DOCUMENT RESUME

ED 150 019 SE 023 920

AUTHOR	Steiner, Robert L., Ed.; Fox, Fred W., Ed.
TITLE	1978 AETS Yearbook - Science Education: Past or Prologue. Glimpses of the Past as an Aid to the Future.
INSTITUTION	Association for the Education of Teachers in Science.; ERIC Information Analysis Center for Science, Mathematics, and Environmental Education, Columbus, Ohio.
SPONS AGENCY	National Inst. of Education (DHEW), Washington, D.C.
PUB DATE	Nov 77
NOTE	278p.
AVAILABLE FROM	Information Reference Center (ERIC/IRC), The Ohio State University, 1200 Chambers Rd., 3rd Floor, Columbus, Ohio 43212 ($5.50)
EDRS PRICE	MF-$0.83 HC-$15.39 Plus Postage.
DESCRIPTORS	*Inservice Teacher Education; *Preservice Education; *Science Education; *Science Education History; Science Supervision; Science Teachers; *Teacher Education; Teacher Educators; Yearbooks
IDENTIFIERS	*Association for Education of Teachers in Science

ABSTRACT

In this fifth annual yearbook of the Association for the Education of Teachers in Science, nineteen persons who have been active in science education over the past 25 years have contributed their personal recollections about changes they have seen in science teacher education or in curriculum and instruction in science. The articles include: (1) reflections on twenty-seven years of teacher education; (2) a look at science for children; (3) a review of some revolutionary changes in science education, 1850-1950; (4) a review of thirty years of science education at Harvard; and (5) a discussion of the impact of National Science Foundation institutes on science teacher education. (Author/BB)

1978 AETS YEARBOOK

SCIENCE EDUCATION: PAST or PROLOGUE
Glimpses of the Past as an Aid to the Future

Edited by

Robert L. Steiner
The Ohio State University
Columbus, Ohio 43210

Fred W. Fox
Yearbook Series Editor
Oregon State University
Corvallis, Oregon 97331

Association for the Education of
Teachers in Science

ERIC Information Analysis Center for
Science, Mathematics, and Environmental Education
The Ohio State University
1200 Chambers Road-3rd Floor
Columbus, Ohio 43212

November, 1977

The ERIC Information Analysis Center for Science, Mathematics, and Environmental Education is pleased to cooperate with the Association for the Education of Teachers in Science in producing this Yearbook, funded in part through the Center for Science and Mathematics Education, The Ohio State University.

ERIC/SMEAC and AETS are currently cooperating on a sixth publication. We invite your comments and suggestions on this series.

Patricia E. Blosser
Research Associate
Science Education, ERIC/SMEAC

Stanley L. Helgeson
Associate Director
Science Education, ERIC/SMEAC

This publication was prepared pursuant to a contract with the National Institute of Education, United States Department of Health, Education and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their judgment in professional and technical matters. Points of view or opinions do not, therefore, necessarily represent National Institute of Education position or policy.

PREFACE

This, the Fifth Yearbook of the Association for the Education of Teachers in Science, was initiated during and reflects the spirit of our Bicentennial Year. It contains personal reflections on the historical background and perspectives regarding the growth and development of science education in the United States. AETS President, Patricia E. Blosser, solicited contributions from science educators who have provided long and valuable service to science education. They are science educators who have recently retired or who approach that point in their professional careers. Included are educators who have been first-hand participants in and observers of the growth and development of science education and who have witnessed or have been integral parts of curriculum development movements such as Progressive Education, Life Adjustment, or post-Sputnik activity. These educators have had unique experiences which give perspective to what has happened and perhaps should happen in science education.

Obviously the pool of science educators as potential contributors was larger than those included in this Yearbook. An attempt was made to solicit authors who represented various aspects of science education and science education programs at major institutions. Of the 26 science educators initially contacted, 19 indicated a willingness to prepare material for this Yearbook. The others, for a variety of reasons, declined the invitation. In no way should it be interpreted that the included authors represent all who have made significant contributions to science education.

The only conditions imposed on the authors were a length limitation and a stated deadline. The authors were asked to reflect on science education from their perspective, in terms of its growth and development, the changes which have occurred, and finally what they might see for the future of science education.

An obvious concern of the editor was the possibility of a great deal of overlap in the materials, but as the reader will find this was not borne out. The approaches and content of the authors' materials varied a great deal, including perspectives ranging from degrees of optimism to pessimism regarding the past and future of science education.

President Blosser felt that this Yearbook would fill a definite need by collecting in a single volume the historical perspectives of a number of eminent science educators. I believe that the need has been fulfilled and that current and future science educators should find it an invaluable resource.

I wish to thank the authors who were willing to put their personal reflections of science education to paper for inclusion for this Yearbook. I also wish to thank Patricia Blosser for the opportunity to serve as editor for the Yearbook and a special thanks to the ERIC-SMEAC staff in preparing the finished manuscript for publication.

Robert L. Steiner, Editor

INTRODUCTION

The introduction section in the preceding AETS Yearbook begins with the statement, "The science education scene is a changing one." Few will take issue with this view. Because it is a changing scene we need to be able to decide whether things, when they happen in the future, are really new events or whether they really have occurred before, in some slightly modified form. In *The Tempest*, Shakespeare has one of his characters (Antonio) say, in Act II, Scene I, ". . . what's past is prologue, what to come is your and my discharge."

The science teacher education community as exemplified by the Association for the Education of Teachers in Science has relatively little written history other than that which can be found in some of the yearbooks of the National Society for the Study of Education (NSSE) or which can be inferred from literature reviews in some doctoral dissertations. The focus of *Science Teacher Education; Vantage Point 1976* was the future of science education as seen by the contributors to that volume.

It is hoped that *Science Education; Past or Prologue* will prove a worthy companion volume. In this Yearbook persons who have been active in science education over the past 25 or more years have contributed their personal recollections about changes (or lack of them) which they have seen in science teacher education or in curriculum and instruction in science.

I am grateful that these persons were willing to share their expertise and personal experiences with us. May you enjoy reading the chapters as much as I did when I received each of them.

Patricia E. Blosser
AETS President, 1976-1977

TABLE OF CONTENTS

TABLE OF CONTENTS--Continued

SCIENCE EDUCATION: PAST or PROLOGUE

Glimpses of the Past as an Aid to the Future

J. Darrell Barnard was born in Colorado in 1906 where he acquired his elementary and secondary education. He was awarded his A.B. in 1931 and his A.M. in 1934 from Colorado State College. His Ph.D. was granted from New York University in 1941.

Dr. Barnard served as a teacher and later as an administrator in Colorado public schools between 1926 and 1936 and as an instructor in the laboratory school at Colorado State College between 1936 and 1938. He returned to Colorado State College in 1944 as Chairman of the Division of Science and Mathematics after having served as a consultant with the Kellogg Foundation and two years with the United States Army in Bombardier Training. Dr. Barnard remained at Colorado State College until 1947 after which he returned to his doctoral-granting institution, New York University, where he remained until his retirement in 1973. He served as Chairman of the Department of Science and Mathematics Education from 1953 until 1971. He currently holds the rank of Professor Emeritus at New York University.

Dr. Barnard has been active in numerous professional organizations including AETS, NARST, NSTA, NSSE, NABT, and AAAS. He was selected as a AAAS fellow and served as president of NARST in 1953 and as president of NSTA in 1962.

Dr. Barnard conducted numerous workshops for elementary and secondary teachers throughout his professional career and served as a consultant for many school systems.

Throughout his professional career he has actively researched and has published extensively in science education and general education journals. He served as Chairman of the NSSE 59th Yearbook Committee and contributed to several chapters. He authored an elementary and junior high school science series and served as Associate Director of the COPES Project from 1962 until 1976.

Dr. Barnard's service to science education has been widely recognized. He was selected to give the Inaugural Lecture of the Abraham M. Weckstein Memorial Lecture at New York University and was presented the New York University Distinguished Alumni Achievement Award in 1972. His service was also recognized by the National Science Teachers Association with the NSTA Distinguished Service Award in 1970.

REFLECTIONS ON TWENTY-SEVEN YEARS OF TEACHER EDUCATION

J. DARRELL BARNARD

Professor Emeritus of Science Education
New York University
New York, New York

In our efforts as science teachers, teachers of science teachers, or teachers of teachers of science teachers, each operates from a frame of reference that is highly individual. We may subscribe to a point of view generally supported by other science educators; however, our interpretation of it as well as both the manner and the commitment with which we apply it are uniquely our own. For this reason there have been, and will continue to be, as many approaches to the education of science teachers as there are persons practicing the art. It is with this in mind that I shall attempt to write about the education of science teachers as I have experienced it during a 27-year period, 1936-1971.

THE BEGINNING FOR ONE SCIENCE EDUCATOR

During the 1930s two major events captured the imagination of those who were looking for more reasonable and effective ways of educating young people in science and of preparing prospective science teachers to assume an appropriate role in that challenging enterprise. The first event was the publication of Part I of the National Society for the Study of Education's (NSSE) Thirty-First Yearbook entitled *A Program for Teaching Science* (1). It presented a rationale and a general plan for the development of science programs in schools and the first two years of college that were widely accepted by science educators in this country. The second event was a well-organized and highly active promotion of curriculum revision by the Progressive Education Association (PEA). Through its publications and curriculum experimentation the association exercised considerable influence upon a number of school systems.

Some of us, who were in the formative stages of becoming science educators, were strongly influenced by these two events. A few were privileged to do our graduate work with professors who were responsible for the Thirty-First Yearbook. Some of us also became participants in curriculum innovation as sponsored by PEA.

Through these experiences we came to believe strongly in the following:

1. Schools should make a major contribution to the total development of children and adolescents.
2. Each school subject should have a unique role to play in the lives of young people at different developmental stages.
3. Science in the schools should contribute to the development of students by helping them
   a. to exercise critical thinking in dealing with real problems, and
   b. to understand those science principles having broad application in their daily lives.

For one who had been brought up to accept science as a body of subject matter that was only incidentally related to the ongoing lives of people, it became a challenge to think of science as a school subject that should serve young people by making their lives more meaningful. It was a challenge when, as a teacher, one was faced with the task of helping students identify problems that were not only real to them but which required science to understand the problems better. It was a challenge to help students develop the techniques, to find the resources to deal with their problems, and to exercise safeguards that would make their efforts productive. It was a challenge to make certain that the appropriate science had been exploited in dealing with the problems. It was a challenge to find valid ways to evaluate student development and achievement in self-directed problem solving. It was a challenge to continue one's belief in this as a valid approach to education in the sciences when formerly respected professors of science denounced such an approach as heresy and its practitioners as "dopes."

Those of us who survived the struggles of implementing these points of view generally agreed that, by this approach, we had witnessed changes in students that had never been observed under the "traditional approach" to teaching science. We became so strongly committed to this as a way of education that we were accused of being cultish. Be that as it may, many of us were offered teacher-of-teachers positions in colleges. The offers were based primarily upon our recognized success in working with students in courses where problem solving and "pupil-teacher planning" were the exclusive approaches.

BECOMING A TEACHER OF TEACHERS OF SCIENCE

The challenges we had faced as science teachers in developing the "new" science programs in the schools were relatively simple compared with those we encountered in performing our duties at the

college level. There was the challenge of finding ways in which we could exert leadership from the college level that would bring about the changes in science curricula which our earlier experiences in the schools had convinced us were so desirable. Then there were the problems of redirecting college programs in ways that would prepare our students to become teachers who could implement "new" science curricula such as we envisioned for all schools.

The PEA-Type Workshop

During our earlier experiences in introducing ways of bringing about curriculum changes in the schools and helping teachers to implement those changes, we had been introduced to the concept of in-service workshops for administrators and teachers as effective ways of bringing about the desired change. Here is where the "workshop" idea in teacher education originated and it was quite different from the way in which the workshop idea is applied today.

In the 1930s workshops were generally, but not exclusively, sponsored by colleges. They were designed primarily to assist the participants from one or more school systems in developing more dynamic points of view regarding what the educational programs in their schools should be achieving. Once this was accomplished workshop participants were then given assistance in designing curricula and courses that would implement the point of view. One basic assumption underlying this approach was that fundamental changes in a school's curriculum should take place by democratic processes involving those teachers who will be responsible for implementing the changes. In other words teachers must play an active role in deciding what changes should be made. These workshops were staffed by educational philosophers, specialists in child and adolescent psychology and subject-matter specialists, curriculum specialists, and master teachers. Primary criteria in selecting staff personnel were that they should be amenable to a democratic-dynamic approach to curriculum development and possess the capacity to relate to teachers and their problems in ways that develop mutual respect.

In the workshops the staff spent most of its time in working with individuals or small groups in which the teacher participants asked most of the questions and the staff assisted them in working out solutions that would be appropriate in bringing about changes in their schools. Most such workshops took place during a six- to eight-week summer session. They were frequently conducted in facilities provided by one of the participating schools. In some workshops elementary and secondary students played an active role.

During the academic year following a workshop, selected staff frequently became consultants and visited teachers in their schools to give them follow-up assistance with their plans to modify courses and methods of teaching. Frequently a summer workshop would be followed by another, a year later. This was done to give the previous summer's participants an opportunity to work upon implementation problems which they had encountered and to firm up their future plans. Curriculum development was viewed as an ongoing process, subject to changes from time to time as the need for change was indicated.

A number of administrative problems faced [illegible] ponents of workshops such as those described above. Fir[illegible]t assistance had to be obtained from participating schools and private foundations. In the beginning many colleges did not look with favor upon proposals to give workshop participants academic credit for what the colleges considered to be unscholarly work. Some even questioned the academic qualifications of a workshop staff selected by the criteria mentioned earlier.

As one who served as a director and a staff member of several workshops such as those described above and as one who served as a curriculum consultant to dozens of schools and hundreds of teachers, I developed strong biases supporting the local, indigenous approach to curriculum development and change. The fact that the excellent starts which a number of schools achieved in the 1930s eventually petered out was accounted for by the fact that certain basic propositions in maintaining curriculum change were largely ignored. One was that teachers must initiate and sustain change. The second was that school systems must select teachers who are amenable and then provide the inducement for them to become continually involved. The third was that professional schools for teachers must prepare teachers who are not only competent to teach but who possess the prerequisite competence for such curriculum work. Furthermore, they should provide those curriculum services to schools which professional schools are uniquely qualified to supply. Unless these conditions exist, local schools are doomed to the practice of selecting curricula developed by others and hoping that their teachers will implement them in those ways in which the developers consider to be most effective in educating children.

Experiences in a Progressive Experimental School

Two years as a science teacher in a progressive, highly experimental laboratory school associated with a western college of education provided challenging and formative experiences for me as I looked forward to a career in science education. Many times during the first year I would have given up had it not been for colleagues who were most helpful in my initial struggles to

teach adolescents in a social studies-literature-science unified program. In this program 3 teachers and 60 adolescents, ranging in age from 15 to 18 years, developed a number of short-term problem units based upon the interests of the adolescents and the assumed competency of the teachers. There were three problem units under investigation during each six-week period. Each unit was developed as a cooperative effort by students and a teacher. At the conclusion of each six-week period a review and evaluation forum was conducted with both students and teachers participating. After the forum, students selected another problem unit of interest for investigation during the next six-week period. For the program to succeed, it was highly essential that teachers developed an understanding of students that went much deeper than their academic abilities. Furthermore, teachers repeatedly had to venture into problem areas which were quite different from those usually included in their subject areas. In coöperation with students, teachers located resources and prepared materials for use in the investigation of each problem unit. Student progress was assessed in terms of the manner in which the students applied themselves to the investigation of selected problems and to the organization of relevant ideas.

None of us had had training for working with students in such an undefined, open program of study. None had had the experience of applying the subject matter and study skills of his speciality to the type of problems suggested by these students for investigation. None of us had been prepared to evaluate student achievement based solely upon investigatory skills, attitudes, and work habits as demonstrated in day-to-day behavior. As mentioned earlier it took a great deal of support from colleagues, especially the director, to keep me afloat during the first year. Never have I worked harder or received more satisfaction from my efforts as a teacher. I knew that what we were doing was making a difference in the lives of the 60 adolescents with whom we worked for two hours every day.

Graduate Study with One of the Greats

For me the unified study experience, described above, was followed by two years of graduate work with one of the principal contributors to the Thirty-First Yearbook, Professor Charles J. Pieper. He was a scholarly and effective proponent of the point of view that a study of science, particularly for grades 7, 8, and 9, should contribute to specific human behaviors. He considered the behaviors, in general, to be of two kinds: 1) behaviors which satisfy mental curiosity concerning phenomena and applications in the field of science--that is, the purely intellectual adjustments to the environment; and 2) behaviors which represent the practical adjustments to the environment. He considered the desirable

adjustments to include those which young people and adults actually do make or try to make in the unspecialized activities of life and also those which, upon the basis of education in science, they are able to make. He involved his graduate student in preparing comprehensive lists of the major aspects of the environment in which problematic situations require intelligent adjustment. He delineated criteria by which selection of adjustments to be developed by studying science should be made. Under his supervision many of his doctoral students undertook research studies designed to determine items of scientific knowledge and problem-solving skills that would help young people and adults make the adjustments.

This great professor's point of view, and the methods he proposed for implementing it, provided for me a more organized approach to curriculum development in which science was related to the lives of young people than was provided by the laboratory-school approach described earlier. The laboratory-school approach was more spontaneous and opportunistic. However it did have the advantage of involving young people in thinking about problems, selecting those which they would like to investigate, and planning with their teacher how the investigation would be conducted. The educational benefits derived from such an approach have been demonstrated again and again by those teachers who have been willing to give the time and effort that are needed to make it work.

ADMINISTERING PROGRAMS FOR EDUCATING SCIENCE TEACHERS

Hopefully this sketchy background will give the reader some idea of those experiences which I consider to have had great influence upon shaping my point of view and developing the skills with which I approached a position in science education at New York University where I later became chairman of the Department of Science Education. In this position I was expected to provide leadership in designing science courses for "education" students and planning undergraduate programs for the education of prospective science teachers and graduate programs for science educators. I was involved in this work over a period of 25 years. Although I considered myself to be progressive in point of view, I have compromised many times wherever it seemed desirable in order to achieve goals for the common good.

The remainder of this chapter will deal with the education of science teachers based upon my experience since 1947.

The Influx of G.I.s

In 1947 veterans from World War II were still returning in large numbers to colleges. Many who sought admission into our department had not completed their undergraduate work before entering the armed services. A large proportion of them had poor academic records. Some had even "flunked out." Now as they were returning to civilian life they were determined to be admitted to a college program that would qualify them for teaching positions in science. Since those with such records failed to meet admission standards other means for screening them were instituted. These included a standardized text of academic ability and an extensive personal conference with a member of the science education staff. I reviewed the records and conferred with approximately 100 of these young men. I have always felt that the four years I spent in the Air Force during World War II aided me greatly in conducting conferences with these men and in making judgments regarding their qualifications to undertake additional college work that would prepare them to be science teachers. Over 90 percent of those who were screened by me were eventually admitted. All completed their degrees and some with distinction. Without exception they were above average in their performance as student teachers.

Reactions to Admission Requirements

The experience related above has made it impossible for me to accept prior academic achievement and other so-called objective evidence as the only criteria by which judgments are made regarding admission to professional programs for the education of science teachers. The out-of-school experiences of an individual, his personal evaluation of those experiences, his concept of teachers and of teaching, his maturity, and the intensity with which he desires to become a teacher are all important in making predictions about those who desire to become science teachers. The prospective teacher should have had work experiences of sufficient duration and interacting relationships with people of various types. Through such experiences he should have been challenged to assess his system of values.

The Advisement of Prospective Teachers

Once a student is admitted to a teacher education program he should be assigned an adviser whose responsibility goes well beyond merely signing his registration card. It is an adviser's responsibility to assist his advisees in dealing with problems they encounter in their efforts to be successful as students and to see how their work fits into a reasonable pattern leading to their preparation for teaching. When and where the pattern becomes unreasonable it is the adviser's responsibility to encourage the school to make changes.

Thus the adviser should be one who understands the basic rationale upon which the program is based and its relevance to the education of a science teacher. He should be one who is highly regarded by other members of the staff. He should be one who is respected as having been a successful teacher at the level for which the student is being prepared. Above all he should be one who can exercise patience and empathy in dealing with problems brought to him by his advisees. He should be willing to seek the assistance of his associates wherever needed in providing his advisees with sound advisement. Student advisement should be assigned to only the very best professors in the department.

Observations, Methods, Practice Teaching: An Articulated Experience

My efforts over a period of thirty years to find more effective ways of preparing students to be competent science teachers have led me to believe that the student teaching experience is far and away the most critical phase of a prospective teacher's professional education. At the undergraduate level all professional courses should make this experience their central concern. In the laboratory school that was mentioned earlier I taught, in 12-week sequences, "short courses" in chemistry, physics, and biology for those laboratory school students who had some good reason for taking the specialized sciences. I also taught the methods course required of the college science majors. Everything that was done in the methods course was geared to what was going on in the "short courses" and the methods students were required to observe as I worked with these young people. For example, the college students participated in planning lessons to be taught in the "short courses." They observed the teaching and later participated in critiques of the lessons as they were taught. As the course progressed, students from the methods course were encouraged, but not required, to teach a lesson from time to time. In both the planning and critique sessions it was possible to bring out in a most practical manner all of the important matter that is covered in a methods course. Later when these students did their practice teaching they did it in my classes under my supervision.

By the time I had arrived at the university, as a professor of science education I was convinced that prospective secondary school science teachers should have something more than a "bag of tricks" as preparation for their work as a science teacher in the schools. I believed then, and still do, that they should be well on their way to developing a philosophy of science teaching and that this should begin serving them as a frame of reference out of which they make decisions regarding such questions as: What science is important to teach? How should it be taught? When do you know that learning has taken place? What should be the role of the student

in the learning process? What should be the relationship of science to other subjects in the secondary school? This job was to be done in a sequence of courses such as: Directed Observation in Secondary School Science, Methods of Teaching Science, and Practice Teaching. At the master's level these courses were to be followed by a course dealing with "the science curriculum." Obviously this sequence of courses had to be carefully articulated if students were to become reasonably knowledgeable about science teaching and relatively capable practitioners.

The plan that I found most successful in accomplishing the above purposes was for one professor to handle the observation experiences, the methods course, and student teaching for the same group of students. This I considered important for several reasons. The articulation from course to course could be dealt with effectively. The professor could become better acquainted with his students and they with him. He would come to know them as individuals and thus be able to adapt his approaches to their unique needs. It may sound repetitious in mentioning again student needs. However, in teacher education I believe such concern should be paramount if we are to educate well-integrated teachers, who behave as human beings and relate to their students as such.

Observation as a Meaningful Experience

The observation experiences for prospective secondary school science teachers should begin in the elementary school, continue into junior high school or middle school, and culminate at the high school level. This should be done to encourage students to think of precollegiate education as a K-12 continuum. It is also desirable for them to observe how the methods frequently change from those involving maximum participation of children to those involving maximum direction by the teacher. The students observe that children often ask most of the questions in the elementary school, whereas teachers generally ask most of the questions in the high school. Questions should then be raised regarding such practices as a desirable progression in the education of young people.

The K-12 observations should be used to set the stage for developing teaching strategies that encourage maximum involvement of students in the learning process. I feel very strongly that student observation in the schools should be selective and carefully guided to be worthwhile. Schools, classes, and teachers should be selected that will give a representative view of how science is taught under a variety of conditions. Each series of observations made by students should be closely supervised by the professor responsible for their work. This should be done to make sure that students "see" what is most relevant in the classes they observe. Each series of observations should be followed by a seminar in

which specific incidents from their observations are used in establishing tentative lists of criteria by which teaching should be evaluated. The criteria developed by the above process should be used as the take off for the methods course.

The Bridge Between Observation and Method

It is desirable for students to do their observation and take their methods course concurrently. Where this is possible the seminar following each series of observations should be extended into the methods course. There should be at least a half day, per week, of supervised observation in the schools followed by a half day of methods work. The seminar or methods course should be conducted in the science teaching center where relevant references and other teaching materials are readily available and where the prospective teachers get guided practice in using them. The methods course should be conducted as a workshop based upon the experiences of students during their observations. The goal of the methods course should be to initiate an independent approach to the teaching task and to deal with the problems it entails.

Practice Teaching

Practice teaching of at least one semester should follow in a natural uninterrupted manner from the work described above. From their observation experiences students should identify two or more teachers with whom they would like to do their practice teaching. The professor should assume responsibility for helping students make all necessary arrangements for their practice teaching. He should arrange to have at least two practice teachers in each school. This makes each one feel less alone. During the concluding weeks of the methods course students should get the assistance of their professor in making preliminary plans for their practice teaching assignment.

It is highly desirable that the professor of the methods course serve as the coordinator of practice teaching. He should also supervise at least two student teachers. As coordinator he should conduct biweekly seminars for all practice teachers and their supervisors. The seminars should deal with problems encountered by students in ways that encourage them to become increasingly independent. In evaluating the achievement of a student in his practice teaching, major consideration should be given to evidence that he is becoming increasingly capable of analyzing his teaching, generating ideas of ways in which he can overcome his deficiencies, and applying his ideas in making progressive improvements. If at the conclusion of his practice teaching a student has made substantial progress in these regards, he is well on his way to becoming a good science teacher.

Practice Teaching as a Cooperative Venture

There are times when a student may be assigned to a cooperating teacher who, for various reasons, thinks that "college people" have little concept of how science must be taught in his school. Furthermore, that what they teach in education courses, particularly in methods courses, is so "theoretical" or idealist that it has little relationship to what has to be done in the classroom. Such teachers frequently tell students to forget what they have been taught, that they will show the students how it should be done. Where this happens it is obvious that the cooperating teachers have not been properly selected or that a good working relationship has not been developed between the school and the college.

Schools depend upon colleges for qualified teachers. Colleges depend upon schools for the most critical component of the prospective teacher's education--the induction into the profession through observation and practice teaching. For these reasons it would seem that the education of teachers should be considered as a cooperative venture between schools and colleges. There are ways of accomplishing this through observation, methods, and practice teaching.

The professor should use every possible opportunity to become acquainted with schools and science teachers within the service area of the college. There are frequent occasions when it would be helpful to have the advice or opinions of teachers or to observe youngsters under different conditions. These and many other occasions when information from the schools is needed by the college provide quite appropriate reasons for requesting permission to visit schools. During these visits the administration and teachers should be made to feel that they are being helpful and that their expertise is appreciated. Under no condition should cooperating teachers be made to feel threatened by the college. Visiting with teachers in a relaxed environment over coffee can do much to build good relations. From time to time selected teachers should be invited to discuss with one of the college classes some idea or approach being developed in his school.

Through these kinds of association with schools and teachers one soon finds those who would be willing to cooperate with the college in programs of teacher education that would be mutually profitable. I emphasize mutually profitable because too often schools and hard-working teachers feel they are being put upon when asked to work with practice teachers. Before students report at a school for practice teaching they should be encouraged to find ways in which they can provide a service to the school and particularly to the cooperating teacher with whom they will be teaching. Since this may require the students to put in time beyond that normally required

for practice teaching they must be made to feel that such service is a part of their responsibility. Students with whom I have worked have been encouraged to find ways of assisting teachers in their schools so that teachers will actually miss them when their tour of duty is completed. In fact I have used this as one criterion of their success as student teachers.

Cooperating teachers should be encouraged to observe the lesson taught by the practice teacher at the time his college supervisor observes him. Other practice teachers in that school should also observe their associates on those days. The critique for the day should be attended by the cooperating teachers, practice teachers, and the college supervisor. The critiques should be coordinated by the supervisor who encourages everyone, but particularly the cooperating teacher, to analyze the lesson as it was taught. The first go around should always be the prerogative of the one who taught the lesson. The critique should also be summarized by the student who indicates both the strengths and weaknesses of his lesson and what he proposes to do to overcome his weaknesses. The coordinator should keep the critique from becoming a threatening experience for the student. An effort must be made to maintain it as a constructive approach to improving teaching practices. The supervisor should help the cooperating teacher understand that his participation in the critique is most essential. After all he is the only participant who is a fulltime teacher. He is the only one who understands the local situation, particularly the idiosyncrasies of the students in his classes.

The Fifth Year

The fifth year, or master's degree, work for science teachers should provide them opportunity to advance their background in science with courses that have been specially prepared to meet the needs of secondary school science teachers. They should also take a science curriculum course which does two things. First, it should require them to become knowledgeable regarding nationally recognized science curriculum efforts at the elementary and secondary school levels. Secondly, it should require them to engage in curriculum development exercises in order that they might appreciate the kind of effort involved and develop some of the skills. A course in the history of science and its social implications should be required. Independent study should be available to those who have problems or interests that justify it. All courses should be conducted in ways that require maximum involvement of students through reading, discussions, and writing. The goal of the fifth year should be to turn out teachers who have attained a reasonable degree of sophistication in their profession. The goal of becoming a master teacher cannot be attained in less than five years of experience. The judges of when one becomes a master are one's students and one's associates.

Elementary School Science

So far I have dealt with teacher education as it applied to the preparation of secondary school science teachers. The more difficult task is that of designing practicable programs that will prepare the prospective elementary school teacher to teach science. There are a host of problems involved. I'll mention only one. Elementary science has come to mean different things to many people. An examination of any of several books in the teaching of elementary science used in colleges impresses one with the breadth of science covered. College programs designed to prepare elementary school teachers leave previous little time for elementary science. So little, in fact, it would appear impossible to do anything of significance for the prospective elementary school teacher. And that is about what happens in most instances.

One approach to the problem would be to redefine elementary school science and put manageable limits on what it covers. In various ways this has been done by such new elementary science programs as the Science Curriculum Improvement Study (SCIS), Science--A Process Approach (SAPA), and the Conceptually Oriented Program for Elementary Science (COPES). These programs have many common denominators. Some effort has been made to delineate them and to use the delineation as a basis for an integrated course in science and science methods that would better prepare prospective elementary school teachers for the challenges which face them if they take positions in schools where it is considered important to teach science. Efforts of this nature should be encouraged.

College Science Teaching

An effective way of preparing prospective teachers of the general-education science courses at the college level was used by us at the university for a number of years. In our department we offered as many as eight sections of a biological science course each semester for nonscience majors in the school of education. As many sections of a physical science course were offered each semester for the same students. For each section graduate students served as laboratory assistants. Some sections were taught by teaching fellows who had previously been laboratory assistants. Each semester I taught one section of biological science. There were generally at least three teaching fellows teach the other sections. Each week the teaching fellows and laboratory assistants met with me to plan the work for the following week in our respective sections and to consider problems encountered during the current week. We also visited each other's classes regularly. In the weekly planning sessions it was possible to involve the graduate students in discussion of practically every problem one encountered in organizing material, teaching, getting students involved, maintaining good

working relationships with students, and evaluating their achievement. In working with these prospective college teachers every effort was made to preserve the individuality of each participant.

Looking back, I think this approach to the education of science teachers was the best I have ever used. I worked with the young people as a peer. My job, as I conceived it, was to ask the key questions and encourage everyone to "get into the act." However, it wasn't easy to avoid inflicting my approach upon them as the approach. I'm sure that I did at times even though I tried not to.

IN CONCLUSION

During the time that I was directly involved in the education of science teachers I modified my approach frequently in order to achieve better results. Never did I find one approach that I could accept as the ultimate answer. I guess I was always hopeful that one day it would come. But it didn't, and now I can see that its evasiveness is what made the search so challenging.

REFERENCE

1. National Society for the Study of Education. Committee on the Teaching of Science. *A Program for Teaching Science.* Thirty-First Yearbook, Part I. Chicago: University of Chicago Press, 1932.

N. Eldred Bingham was born in 1901 in Ohio. His early education was obtained in Ohio schools. After graduation from high school he attended Hiram College and The Ohio State University where he received his B.S. in Agriculture in 1923. He received a B.S. in Education from Kent State University in 1926. His M.A. and Ph.D. were both awarded from Teachers College, Columbia University in 1930 and 1938.

Dr. Bingham served as a science teacher-administrator in Ohio secondary schools between 1923 and 1926 and as a science critic teacher for Hiram College from 1926 until 1929. He was a science instructor in the Montclair Demonstration School at New Jersey State Teachers College between 1929 and 1932 and a science critic teacher at the Lincoln School of Teachers College from 1932 until 1944. Dr. Bingham functioned jointly as an Assistant Professor of Science Education at Temple University and as Headmaster of the Oak Lane County Day School during the 1944-1945 school year. From 1945 until 1950 he was an Associate Professor of Science Education at Northwestern University. He moved to the University of Florida in 1950 as Professor of Science Education where he remained until his retirement in 1971. He currently holds the status of Emeritus Professor at the University of Florida.

Dr. Bingham has been an active member in numerous professional organizations including NSTA, NARST, AETS, NABT, CESI, NEA, ASCD, Florida Association of Science Teachers and AAAS. He was elected a fellow of AAAS and served as president of the Florida Association of Science Teachers in 1956, as president of NARST in 1950, and president of CESI in 1952.

Dr. Bingham directed a half dozen NSF summer and inservice institute programs between 1959 and 1963 and also directed USOE Teacher Fellowship Program from 1966 until 1968. He also served as a science consultant for Teachers College, helping to establish teacher institutes in India between 1962 and 1964. He served as a consultant with many education and quasi education organizations and as a consultant for several science film projects.

Dr. Bingham has authored and coauthored several books and contributed to a number of other major publications including the NSSE 59th Yearbook.

Dr. Bingham was awarded the CESI Award for Service to Elementary Science in 1971, an NSTA Citation for Distinguished Service to Science Education in 1973, and an AETS Award of Recognition for Meritorious Service in 1977 as Science Educator and Editor of <u>Science Education</u>.

CHANGES IN SCIENCE EDUCATION DURING THE PAST 60 YEARS

N. E. BINGHAM

Professor Emeritus of Science Education
University of Florida
Gainesville, Florida

My perception of changes in science education is, of course, greatly influenced by my involvement in it. In high school (1916-19) I studied general science, biology, physics, and agriculture. In 1923, I received my bachelor's degree from The Ohio State University in agriculture with an excellent preparation in the sciences of botany, zoology, genetics, animal husbandry, chemistry, physics, and agricultural engineering. Later I completed a B.S. in Education at Kent State University and Master's and Ph.D. degrees from Columbia University.

My experience as a public high school science teacher began in 1923 and continued through 1927. Beginning in 1926 I was a science critic teacher at Hiram, Ohio, from 1927 till 1932 a demonstration teacher in the Laboratory School at New Jersey State Teachers College at Montclair, and from 1932 till 1944 a general science and biology teacher at the Lincoln School of Teachers College, Columbia University. Thus from 1926 to 1944 I was involved in science teacher education as a critic teacher and as a demonstration teacher and since that time as a teacher of elementary and secondary science methods, supervisor of science interns, and coordinator of science education programs at Temple University, Northwestern University, and since 1950 at the University of Florida. My experience has also included the teaching of summer session courses in several universities as well as a two-year stint in India to help upgrade science and mathematics teaching.

Let me discuss in this order the instructional materials, the classroom instruction, the preparation of science teachers, and finally the 1970s and beyond.

INSTRUCTIONAL MATERIALS

Prior to 1930 the texts used were logically organized according to the discipline. They were written by scientists rather than by educators. A minimum of laboratory experiments were included, using standardized equipment with everyone doing each of the experiments. The experiments were designed primarily to illustrate the concepts to be taught and these experiments were recorded in a laboratory manual.

Curriculum workers and authors of textbooks realized the duplication in separate botany, zoology, and physiology courses, so general biology replaced these separate courses. However, this transition was somewhat stepwise. I remember teaching a general biology text in the early thirties that was divided into three sections--namely botany, zoology, and human physiology. However, the economics of studying such things as metabolism, respiration, genetics, and the like became firmly established at this time. Physics and chemistry continued as separate courses during this period but became established as upper level courses, with general science being offered first as a 9th grade course and later as a 7th, 8th, and 9th grade sequence. Many of the basic principles common to both physics and chemistry were included such as heat, light, sound, chemical energy, mechanical energy, magnetism, and electricity. Transfer of energy was emphasized. Common technological devices such as simple machines, pumps, telegraphs, telephones, and radios were studied. With each new technological advance, authors felt obliged to add to the text, making it tedious. The emphasis was shifted from the understanding of basic principles and processes with improved experiments and demonstrations to "reading about" science. There was also a shift in emphasis in texts to include more applications of science in daily life.

Just prior to 1920 Smith-Hughes agriculture was introduced into many of the schools. My agriculture teacher was perhaps the best teacher I had. He taught by involving his students in projects--a method to receive great emphasis during the thirties and forties due to John Dewey and William Kirkpatrick.

Nature study was taught in the elementary school--largely as an incidental science. Emphasis was mainly on observations and trying to account for what one observed. Identification of various plants and animals and the study of how they lived were accompanied by the study of rocks and minerals, weather and climate, and the like. Frequently anthropomorphic explanations were given. Near the end of the twenties an organized elementary science program developed by Gerald Craig began to replace nature study.

The great economic depression beginning in 1929 and extending for the next two decades had its effect. Texts emphasized more and more those aspects of science that could be used in everyday life. Basic principles and concepts, or "big ideas" as they were called, served as a skeleton for the texts but those "big ideas" that were related to personal, social, and community needs were stressed (5). Vocational ends were considered.

Authors of texts tended to be teams of science educators and classroom teachers rather than scientists. A psychological order was emphasized rather than a logical, scientific organization. Chemistry and physics were replaced in some cases by a two-year sequence of physical science--a trend still evident today in the Federated Unified Science Education (FUSE) program. The textbook publishers sensed and responded to state textbook requirements and employed teams of authors to produce what the market wanted. Reading and testing tended to replace experimental methods of teaching. Controversial content disappeared from the texts. Such trends continued until sputnik and then suddenly we had scientists again in the picture, along with science educators and classroom teachers, sponsored by the National Science Foundation (NSF) updating the science in the new biology, earth science, chemistry, and physics programs. The aim was to produce scientists. The shift in content was truly amazing. These texts, developed in the sixties, are widely used and the content is also widely dispersed in other commercial texts.

It was found, with the integration of the school systems, that many did not want to become scientists nor did they have the drives and skills to cope with the sciences of the sixties. Furthermore many multimedia materials became available and more and more today these are being used in individualized instructional programs.

CLASSROOM INSTRUCTION

During the twenties and before, instruction was largely dominated by Carnegie Units of organization, college entrance requirements, and--in states like New York--by a regents examination. In the decade that followed, Wilford M. Aiken of Ohio State carried out his significant Eight-Year Study (1). The aim was to free teachers and curriculum personnel from the dominating effect of the college entrance requirements.

Prestigious colleges, such as Harvard, Yale, Princeton, and many others, agreed to take the graduates of 30 selected progressive schools upon the recommendation of the principal. These progressive schools were then freed to organize and teach the best curricula they could devise. What happened to a large random sample of students

taught in these schools was carefully studied through eight years of high school and college. These students were matched against carefully selected students from traditional high schools. It was found that the graduates of these progressive schools equalled or surpassed their counterparts in their academic work in college and they were considerably superior in student leadership in the various colleges. Also the more progressive the high school from which they came, the more the students excelled. (I was fortunate to teach for 12 years in one of the most innovative of the schools, the Lincoln School.)

The Eight-Year Study did much to improve classroom instruction. It freed science teachers and other educational personnel to use their own judgment in improving instruction. The science prone were discovered and nourished by opportunities for advanced and more specialized study. Field trips, both local and extended, were planned for special groups; group work with demonstrations, individual and group projects, and meaningful investigations became more prevalent.

Sometimes teachers teamed together to teach correlated and integrated courses. Perhaps as delightful as any of my teaching experiences in the mid- to late-thirties was to team teach with social studies teacher Alice Stewart in the Lincoln School of Teachers College at the ninth grade level an integrated course entitled "Living in a Machine Age." Emphasis was placed upon individualized laboratory work. We used library reference materials much more than texts. Dependence on a text subtly implies that what's in the text is all there is to know! On the other hand, a good library is boundless in its stimulation to further activity.

With the incipience of new programs in the sixties students were enabled to act as scientists in the laboratory--providing the schools had the essential equipment and science teachers who knew what to do. Process was stressed more than closure on particular concepts. Experiments were interpreted taking into account probability-uncertainty. As mentioned above, since the late sixties there has been much less classroom teaching with much more selfpaced and also individualized instruction. This shift has made it possible for each one to work at his own rate. However much has been lost in communicating one's ideas to his peers. A student misses the opportunity to challenge others and to defend his own ideas--an important skill for being able to interact with others.

At the elementary level many programs were developed emphasizing, as at the secondary level, the processes of science. Children were placed in investigative situations where they worked as scientists carrying out the prescribed activity. I, personally, doubt that sufficient emphasis has been placed on concept development. As

David P. Ausubel has made clear the organizational structure of the concepts one possesses has much to do with what one learns. Isolated, unrelated ideas are quickly forgotten (2). When one can relate a new activity to some aspect of a bigger concept than the one illustrated then the relationship discovered enhances his organized concept and often results in a new level of understanding.

SCIENCE TEACHER EDUCATION

Early attempts at science teacher education as I experienced them were to involve the prospective teacher as a scientist in studying some aspect of science. Perhaps Joseph R. Lunt and Dennis C. Haley in the twenties did this better than anyone at the time (4). They organized a series of activities for many different units. Some of the units were air and oxygen, carbon dioxide, fuels and fine kindling, heat and conduction, convection, and weather. About a dozen simple experiments for each unit were carefully described, a diaphragm of apparatus was provided and appropriate questions were asked which guided the experimenter. All required apparatus for each experiment was stored in a metal box about the size of a footlocker. In the methods courses prospective teachers learned the basic principles of the science studied as they performed the experiments. Then they shared their experiment with others and led them to understand the concepts involved. They also developed the skills to do demonstration teaching or to aid students in so doing.

Students were led to do hypothetical thinking--to find answers in the activity they performed. Such experience enabled them to go beyond what they had experienced by devising new ways to test ideas, to hypothesize, and to design equipment to test the ideas experimentally. The science learned in the methods class supplemented their other science courses. Frankly I value what I learned with these materials in this program more than anything I've found since.

From the thirties through the fifties there was less emphasis on the science to be taught and more emphasis on the psychological and educational techniques and skills. Practical aspects became a part of the science internship program and frequently the supervisor was not a science educator. However, in the elementary science methods courses teachers were taught as they were expected to teach.

With the advent of the elementary and secondary programs of the sixties experimental procedures aided both prospective and inservice teachers to learn science as they were teaching. This practice continues to be characteristic of most elementary and secondary science methods courses. T . extensive summer institute programs supported by the NSF did much to upgrade the science background of science teachers.

A wealth of many new multimedia materials became available to use in methods classes. Videotaping a student teaching his peers and then analyzing his performance, alone or with his peers, is a powerful technique. A prospective teacher needs help in deciding what to teach, how to organize to teach it, how to teach it, and how to know if he has taught what he decided to teach.

THE 1970s AND BEYOND

Emphasis on "equal opportunity for all" has lowered the top level of science education. At the same time many educationally disadvantaged have had opportunities to learn and many of these formerly disadvantaged students are now procuring a higher quality of education which, in turn, enables them to function adequately in professional and administrative positions.

This emphasis has made it difficult to have ability grouping as before, to organize sequential learning experiences appropriate for talented students, and to organize and teach basic concepts in a class situation. So the students may be deprived of the opportunity to exchange ideas with their peers in stimulating class discussions, while capable teachers may not interact as much with students. Students need situations in which they can develop confidence in their ability to exhibit scholastic leadership recognized by their peers.

Science teachers and others concerned with science education literally have been forced to individualize instruction and to develop individualized programs. Selfpaced programs at both the secondary and elementary levels have been developed. Usually these are optional units which may be individually prescribed for, or selected by, a student.

Taking the school population as a whole, individualization has given students a better opportunity to study at their own level. Formerly many of the weaker students failed science because they were not prepared to study it at the level to which it was being taught. The teacher's role has in large measure shifted from classroom instruction to one of administering some sort of individualized program and for many it has meant extensive involvement in developing audiotutorial instructional materials. When a teacher develops these materials he usually does it at a scholarly level, superior to that possible when he taught a classroom. Even though the possibility for stimulating total class discussion has decreased, a clever teacher can arrange for such discussion with small groups concerned with particular topics while others are busy with audiotutorial materials. These discussions can be superior to total class discussions

for every student can be expected to participate and the level of discussion will fit each concerned individual. What few total class experiences there are, such as special lectures by the teacher or an outside resource person, field trips, or special movies, can be provided with little difficulty.

All in all I consider the movement an improvement for it enables teachers to provide a better program for everyone than happened before. Each student is given the basic structure he needs to learn efficiently in keeping with Ausubellian Theory (2, 7) and he will be working at a level at which it is possible for him to achieve in keeping with Piagetian Theory (8).

Science educators in dealing with what to teach have become aware of the finite resource of energy and materials available to mankind, the rapid diminution of these resources, the limitations of industrial growth, the impact of such growth on the environment, and the "lifeboat" concept of population pressure as expressed by Garrett Hardin (3).

To a greater extent than ever before the general population is applying the approaches of science to the solution of life's problems, yet it must be conceded that to many who have rejected science the astrologers and transcendental meditation groups have much appeal.

In my view, to survive, man must learn to live in harmony with his environment. This is dependent upon his acceptance and use of the approaches of science in solving major problems such as food and energy, the limitations of growth and population control.

I've just completed reviewing Joseph Novak's manuscript entitled *A Theory of Instruction* (6). For the first time in my career I see clearly a theoretical basis for the many often unrelated aspects of curriculum and of teaching that accounts for the best practices I've recognized and promoted. This theory can serve to make education many times more efficient than it has been in the past.

Novak's theory reaffirms the need to systematically plan a curriculum based on a hierarchial ordering of superordinate and subordinate concepts. The efficiency of meaningful learning is increased through the establishment of a meaningful conceptual structure to which the learner can relate his new experiences. His theory further aids educators to select instructional procedures with appropriate exemplars which facilitate relating new concepts to those already possessed by the learner. Novak's theory maximizes concept development by focusing on the relationships of particular concepts to more superordinate concepts.

Since individuals are motivated primarily by success, by ego enhancement, and by aversive action, implementation of this theory focuses upon efficient achievement with resultant ego enhancement The dependence on ego enhancement and aversive motivation characteristic of norm-centered evaluation becomes replaced to a considerable extent with criterion-referenced, mastery-type evaluation. No longer do those who can't quite keep up with the pace set by the teacher suffer repeated frustrations; no longer do those ready to go faster suffer boredom.

By returning to an emphasis on conceptual structure based on David Ausubel's learning theory, by fostering at all levels a habit of relating the appropriate new experiences to the relevant concepts held by the learner, and by fostering habits of careful research on the part of teachers and others to find what concepts the learners hold, the major ills of our schools can be overcome. It is time for the quantum jump made possible by the new insights provided by this theory of instruction.

REFERENCES

1. Aiken, Wilford M. *Adventure in American Education*. Vol. 1, *The Story of the Eight-Year Study*. New York: Harper and Brothers, 1942.

2. Ausubel, David P. *The Psychology of Meaningful Verbal Learning; an Introduction to School Learning*. New York: Grune and Stratton, 1963.

3. Hardin, Garrett. "Living on a Lifeboat." *Bioscience* 24 (October 1974): 561-568.

4. Lunt, Joseph R. and Haley, Dennis C. "The Lunt and Haley General Science Course." Chicago: Central Scientific Company (successors to L. E. Knott, Cambridge, Boston, Massachusetts), 460 East Chio Street. No date.

5. National Society for the Study of Education. *The Objective of Science Teaching in Relation to the Aims of Education*. Thirty-First Yearbook, Part I. Chicago: University of Chicago Press, 1932, pp. 41-57.

6. Novak, Joseph D. *A Theory of Instruction*. Ithaca, N.Y.: Cornell University Press, 1977.

7. Novak, Joseph D.; Ring, Donald G.; and Tamir, Pinchas. "Interpretation of Research Findings in Terms of Ausubel's Theory and Implications for Science Education." *Science Education* 55 (October-December 1971): 483-526.

8. Raven, Ronald J. and Guerin, Robert. "Quasi-Simplex Analysis of Piaget's Operative Structure and Stages." *Science Education* 59 (April-June 1975): 273-281.

Paul E. Blackwood was born in 1913 in Kansas where he received his elementary and secondary education. After graduation from high school he attended Kansas State University from which he received his B.S. in 1935. Dr. Blackwood's graduate education was obtained from Teachers College, Columbia University, where he was awarded both his M.A. and Ed.D. in 1941 and 1953.

After graduation from Kansas State University, Dr. Blackwood taught in Kansas schools from 1936 until 1939. He then moved west to Central Washington State Teachers College where he taught from 1941 until 1945, rising to the rank of Associate Professor. Dr. Blackwood came to The Ohio State University as chairman of the science area of the University School in 1945 and remained until 1947 when he joined the United States Office of Education.

Dr. Blackwood has been an active member in numerous professional organizations including NARST, NSTA, AETA, CESI, ASCD, and AAAS. He served on the executive committee of NARST from 1960 until 1962 and as president of CESI in 1952.

During the time Dr. Blackwood has been with the USOE he has served as a Specialist for Science in the Elementary School, as Science Education Research Coordinator, as Chief of Program Operations Branch in the Division of State Agency Cooperation, and is currently an Education Specialist in the Equal Educational Opportunity Program Unit of the Bureau of Elementary and Secondary Education.

Dr. Blackwood has been author and coauthor of a number of science books for children, including a six-volume textbook series for elementary schools. He has also authored or coauthored many bulletins and books for teachers. His national survey of school practices was a landmark on the status of educational practices of schools of the United States in the 1960's.

SCIENCE FOR CHILDREN

PAUL E. BLACKWOOD

Education Specialist
Equal Educational Opportunity
Program Unit
Bureau of Elementary and
Secondary Education
U. S. Office of Education

In writing about science for children during recent past decades the temptation is great to examine one's own experience and to generalize from it. I yield to temptation.

EARLY EXPERIENCES WITH SCIENCE

I begin by reporting that I reached high school without having knowingly studied "science." I attended a small-town two-room school. I spent four years in the "small" room and three in the "big" room, designations more descriptive of the children than the rooms. The teacher of the big room taught about 22 pupils variously assorted among grades 4 to 8. But from hour to hour or class to class (class being recitation time) one was never quite certain what grade one was in. Our teacher had a knack of involving everyone in activities --study, recitations, play, drill, music, and games--in ways which preserved a graded structure yet erased the distinctions of gradedness. Perhaps this seemed true to us at the time because we believed the various mixes that resulted in grade grouping were simply additional ways of involving us in meaningful activity.

There were traditional subjects. Science was not among them. But among the scheduled subjects there were innumerable activities which were a part of a school day or week but which we were never sure were legitimate school work. We played with magnets, magnetos, homemade telephones. compasses. We collected shells and rocks and soil types from the neighboring hills and fields. We identified the trees on our school grounds and learned the names of plants along the roads and sidewalks. We took trips to study erosion in one pasture which was filled with great ugly ditches in which rain carried untold tons of soil to a receptive river. We collected pond life and observed what happened to organisms that developed in assorted jars around the classroom. We studied weather--temperatures, rainfall, cloud structures, snowfall, winds. We met

periodically at night to look at the stars in a systematic way. We knew the planets and major constellations. There they were in the sky above us.

We did these things with not much more obvious order than my random enumeration of them. We did them for three years as a part of school but a part which we often sensed our parents thought were frills introduced by a teacher who had more interests than could be contained in a normal school day. He gave us freedom to explore and investigate. He provided new materials, objects, things, to stimulate us. He suggested ideas to lead us on. But the funny thing was, we never did study science!

Or so I thought. I went to high school in the county seat. On the day of preregistration I discovered other freshmen (most of them from the city) signing up for a subject they called "general science." Since I had no idea what science was, I carefully avoided it. I hesitated to ask. But I remained curious. And after school started some of my classmates came from general science into algebra or English classes talking about magnets, electricity, the weather, and other such topics. That's science? So I discovered I had been studying science, after all, for several years. I learned also that without ever being introduced to the word *science* those of us in that two-room school had already learned a generous portion of what was included in the general science course.

I am not suggesting that it is a good thing, even if it were possible today, for children to complete their elementary school years without knowing the word *science*. A child would indeed be uninformed if he or she escaped some knowledge of the word in this latter third of the century. But there is a lesson to be learned from my experience: It is the content and methods of science which are important, not merely knowledge of a word. Our experience was unstructured, but interesting. It was fragmentary, but fun. Unscoped and unsequenced, but accumulative. We explored, investigated, experimented, read, talked. We were being like scientists.

PREPARATION FOR TEACHING SCIENCE

In spite of this early introduction to science, I look back on my first years of science teaching and realize that I patterned my methods and approaches more on the examples of my high school and college teachers of science than on the exemplary elements of my elementary school experience.

Special courses in science education for prospective science teachers were not commonly available in most undergraduate colleges in the 1930s and 1940s. A young woman or man anticipating a career

in science teaching took numerous science and mathematics courses. Some of the teachers of these courses were excellent but almost without exception they were unaware of your potential interest in teaching science, and when they were aware of it they rarely gave attention to the art of teaching science except as they demonstrated it by example. And during those years practice teaching in chemistry, biology, or physics was coordinated (and properly so) by the education department. Rarely was there any communication between the college science staff and the education department regarding either science content or educational methodology. Fortunately that condition has changed in many undergraduate schools today.

The day came when you had a high school job teaching algebra, biology, and general science. Your practice teaching had been chemistry. But as the days and weeks and months passed you gradually became aware that, by some alchemy, you had survived your initiation into teaching science. When you had time to think about it you realized that your methods were more like your high school teachers' methods than any impressed on you during your college days. Except (reflection does require an exception) you realized you were following "the" textbook and it was your primary mentor.

Assign, study, recite, do laboratory work--and begin the cycle again. You did these things with confidence. You felt what you were doing was science teaching. Students by and large accepted it and most days you were satisfied with the way you and the students were using the textbook. The content was there to be learned.

Then you went to graduate school. You discovered that science was broader than you ever before realized. It had to do with methods of inquiry, with attitudes, with a role in society, a relationship to technology. It was a changing body of knowledge. It was in fact not a fixed thing at all. You met leading science educators who were thinking seriously about "science and society." Your broadened education included ecological studies, science and politics, philosophy of science. These new opportunities revealed that the boundaries between and around bodies of knowledge are man made; classifications are invented to enable us to grasp likenesses and differences among phenomena and objects. Classifications are useful to us in communicating. They help us refine our generalizations. Zoology, botany, biology, astronomy are not the ends of science. They are useful tools of scientists. So for me, and probably for many other science teachers, graduate study in science education stimulated the need to seek better answers about the purposes for teaching science.

Having experienced these broadened viewpoints of science and the role of science teaching in our society, I was prepared to understand the striking resemblance between potentially effective science teaching and the experiences in science which I have recalled

from my elementary school days. This insight was fortunate because it came at the same time my professional development turned to science in the elementary school.

SCIENCE TEACHING IN THE ELEMENTARY SCHOOL

What were we saying in the 1950s and early 1960s about science teaching in the elementary school? To refresh my memory, I have turned to some notes of talks I gave before science teaching groups during that period. I find three themes recurring in discussions with elementary science teachers:

1. What science *is* must be better understood by elementary teachers.
2. Science programs for children should take into account what we know about children's development and how they learn.
3. Science is important for all citizens.

As we look back to that period are there ideas in these themes that continue to be relevant for consideration in the 1970s and 1980s?

1. What is science?

Science, we said, has a twofold nature. It is a composite of procedures and methods by which people have learned to achieve control of parts of the environment for study and to attain warranted conclusions which we may designate as "the facts," "the truth," or "valid knowledge." Science is an experimental method which people use to discover new information about our universe.

Science is also the new information arrived at through the tested methods of inquiry. Such information may be categorized and classified into bodies of knowledge--geology, physics, chemistry, etc., which tend to condition our ways of observing and interpreting the world we live in. The knowledge in these categories also conditions our views on life and on the relation of man to the universe.

With an understanding by elementary teachers of these two aspects of science (methodology and organized knowledge), it remained to challenge them to use the methods of scientists as they work with children in order that children might learn science in ways that would be most meaningful. But the definition of science outlined above seemed to require further elaboration to be of practical value to elementary teachers. It required another approach which would clarify its meaning in terms that would influence and guide teaching. So we said (hopefully) that *science is what scientists do* when they are being scientists. This required an identification of what scientists do. What do they do?

Scientists make descriptions of our natural world. They observe, measure, investigate, analyze data. They use their senses. They describe what is, what happens, how many, how far, when .... They make descriptions of events, of phenomena, of relationships.

Scientists seek valid explanations. They try to explain. They seek out relationships, interrelationships, connections between events.

Scientists make predictions. They speculate, they hypothesize. Key words and phrases for them are "perhaps," "maybe," "if--then," "my best guess is--," "possibly--."

Scientists communicate their descriptions and explanations and predictions to others. They build their findings into verbal statements which have meaning for others. They state principles, generalizations, laws, concepts, and other organized descriptions of and ways of thinking about our universe.

In order for this somewhat contrived definition, namely that *science is what scientists do*, to be useful we urged on elementary science teachers a kind of logic.

> Science is what scientists do.
> Children learn through doing.
> Therefore, children must have an opportunity in the elementary school to do what scientists do.

Admittedly this was not airtight logic but it placed emphasis on ways children can be involved in learning about their natural world. In that approach there was no intention of developing science programs with the primary objective of preparing children to become scientists. Rather, the motive was to provide teachers with a sense of the importance of involving children in active, investigative learning. A rich science program would involve children in making descriptions (not just reading descriptions), in making explanations (not just reading explanations), in speculating and testing their speculations, in summarizing and communicating their learning to others. There were many ramifications of this approach which seemed fruitful to many elementary teachers.

2. Science programs for children should take into account that we know about children's development and how they learn.

In this theme we found a happy correspondence between the characteristics of scientists and children. For example, children are investigators; scientists are investigators. Both are curious. They probe. They question. They find an almost limitless range of

things and events to explore. The tiny speck of dust on the floor, the full moon, the rain, the squeaky wheel, the smell of clover, the red toy, the dropped spoon, the steaming teakettle, the flat bicycle tire, the Gemini flights (ancient history!), the spider swinging from a broken weed, a wiggly worm. With children the questions are what, how, why, when .... And so it is also with scientists.

The tendency of children to investigate is both an opportunity and a responsibility. As with most generalizations there are exceptions. Some children do not seem too curious. Why? Our opportunity is to capitalize on curiosity when it is there, nurture, strengthen, and discipline it. Our challenge is to develop it when it does not exist. Value had to be placed on curiosity.

Children learn in different ways. This too is a double-edged statement. One edge is that a group of children will benefit from varied, planned approaches to learning. Most children learn better when the same thing is approached in a variety of ways. The other edge to the generalization is that some individual children may learn better from one approach than from another. One might learn best from seeing a film, another from reading about it, another from observing it directly, another from talking with classmates. In teaching science, we urged, teachers dare not settle comfortably into the use of one or two timeworn approaches if they want to be assured that maximum learning is taking place.

We felt confident that *children learn those things which they have an opportunity to do* and to become those things they have an opportunity to be. In a sense some of the goals are both the means and the ends of instruction. We say children are curious. They are investigators. That helps them as they pursue science. Investigation is a *means* of making discoveries. A *goal* of science instruction is to help children develop skills and knowledge which enable them to use that investigative tendency more productively. We say children are creative. That is an asset as a *means* of learning. A *goal* is to nurture and extend creativity. Children are observant. A *goal* is to refine and extend and sharpen this characteristic.

To the extent that children are like scientists they will use those characteristics (the means) in learning science. At the same time, through teaching science we are challenged to preserve and strengthen those traits for increasingly more mature use as children mature (end goals).

3. The Study of science is important
   for all citizens.

The quest for an answer as to what science was of importance for all citizens focused mostly on programs in the secondary schools during the 1950s and 1960s. But the emphasis on the importance of teaching science to children in the elementary school was an evidence that science beginning in the early years was thought to be important for at least all young citizens.

We said confidently in the mid-fifties that the purposes for teaching science in the elementary school are few: "To help young people know more about the natural environment and man's relation to it," "To help children improve their skills for studying the environment," and "To help persons develop attitudes consistent with valid knowledge of the natural environment and of scientists ways of uncovering knowledge."

In a nationwide study of science teaching in the elementary school conducted in the early 1960s school personnel were asked to rate ten selected objectives for teaching science (1): They rated each listed objective as <u>very important</u>, <u>of some importance</u>, or <u>little or no importance</u>. Over 97 percent of the elementary schools considered the following seven objectives as either <u>very important</u> or <u>of some importance</u>:

1. Help children develop their curiosity and ask what, when, how, and why questions.
2. Help children learn how to think critically.
3. Teach knowledge about typical areas of science study such as weather, electricity, plants, animal life, and others.
4. Help children learn concepts and ideas for interpreting their environment.
5. Develop appreciation for and attitudes about the environment.
6. Help children develop problem-solving skills.
7. Develop responsibility for the proper use of science knowledge for the betterment of man.

To the extent that these continue to be acceptable objectives, there remains the perennial challenge of preparing teachers to use the materials and methods which will most effectively help achieve them.

Over the years science teachers have had faith that a scientifically educated nation could deal with and solve many of the problems of life. It was hoped that people would bring to bear on these problems the knowledge and skills that characterize

scientists at work. People would be shaped in their decisions by attitudes and behaviors that are consistent with scientific knowledge. And although that hope has in some measure been fulfilled, there is a growing uneasiness that somet ing more is needed.

THE FUTURE OF SCIENCE EDUCATION

Now it is 1976 and time and events have moved relentlessly, bringing new conditions and new problems. As individuals and as a ation we are not dealing satisfactorily with them. And we ask, is it that science is not the discipline which is basic in our effor s to solve problems, or is that we have been teaching science ineffectively?

Science has never, of se, been expected to do it all. But perhaps we realize now more before that scientists must work cooperatively with humanists, cial scientists, and persons n other areas of human experience to seek ways of coping with emerging problems. Teacher education in science should help prospective science teachers to broaden their vision to in lude an understanding of the potential of other areas, along with science, for solving the world's problems. Along wich breadth of knowledge there must be an ever present willingness by science teachers to reexamine their methods of teaching science. Teacher education should help in this reexamination.

In this reexamination I wo ld urge that we take into account the proposition which I stated earlier, that science is learned in different ways by different persons. his applies als to the content or subject matter that they learn, to resort to an artificial distinction between methods and content. So, I repeat, there is no reason to expect that everyone should study or know the same thing even if it were possible. There is no reason to expect that all children and youth should be taught by the same methods. Suppose that by chance or by design all children in the next ten years were taught by the same methods and that subsequent evidence revealed that that method was "w ong."

It is far better to seek agreement on goals of education and the roles of science teaching in that awesome enterprise than it is to become preoccupied with which is the best method or the best way to teach science. When teachers have continuous help and encouragement in the importance of working with pupils toward acceptable goals they will individually and collectively find numerous best ways of teaching.

Such v   ty as will evolve should be applauded. It should be applauded   alued, evaluated, and shared. In teacher education programs we can applaud, evaluate, and share.

Who has not observed the enthusiasm of children for science in classrooms where the teaching was different from our own? Why was that?

REFERENCE

1. Blackwood, Paul E. *Science Teaching in the Elementary School (A Survey of Practices)*. OE-29059. Circular No. 749. Washington: U. S. Department of Health, Education and Welfare, 1965.

Glenn O. Blough was born in Michigan in 1908. Following his elementary and secondary education in Michigan public schools he attended the University of Michigan from which he received his A.B. and A.M. in 1929 and 1934, respectively. He did advanced graduate work at the University of Chicago from 1939 until 1942 and also at Teachers College, Columbia University. In 1950 he was awarded an honorary L.L.D. from Central Michigan State College.

Dr. Blough was an instructor in the teacher training program at Central Michigan State College from 1931 until 1937. In 1937 he joined the faculty of Colorado State College as an Assistant Professor. He remained at Colorado until 1939 when he joined the University of Chicago faculty as an instructor during his advanced graduate work. His graduate work was interrupted by the war during which he served in the United States Navy from 1942 until 1946. In 1946 he joined the U.S. Office of Education as a specialist in elementary science. In 1954, after eight years with the USOF, Dr. Blough joined the University of Maryland as a Professor of Education. He was awarded the Professor Emeritus rank in 1973.

Dr. Blough has been an active member of professional organizations during his career. he has been a member of NSTA, NARST, CESI, AETS, and NEA. He served as president of CESI in 1950 ana as president of NSTA in 1958.

In addition to his regular duties at the University of Maryland, Dr. Blough has served as an education consultant to the National Geographic Society.

Dr. Blough is the author of over 40 books for elementary school children and for elementary school teachers. A number of his books have been selected for distribution by the Junior Literary Guild Book Club. His books have been translated into 20 different languages. His elementary teachers' methods book has been one of the most widely-used books in the field.

Dr. Blough's contributions to science education have been widely recognized. In addition to the honorary doctorate awarded by Central Michigan State College for his distinguished contributions in the field of education, he was presented the Diamond Award by his students at the University of Maryland in 1958. He was presented Service to Science Education Awards from both NSTA and CESI in 1971.

SOME REFLECTIONS ABOUT ELEMENTARY SCHOOL SCIENCE

GLENN O. BLOUGH

Professor Emeritus
University of Maryland
College Park, Maryland

This is a personal account. It will reflect some trends but it does not intend to be a history. It is certain to contain some evaluation but it's not necessarily planned to assess progress. It is not intended to evaluate any group of programs. It is rather a brief account as seen by one who for many years has been involved as a classroom teacher in science in the elementary school, a consultant in elementary science in the Office of Education, and as a professor of science education involved in the education of elementary classroom teachers who are preparing to teach children as part of the total learning experience of children. If some philosophy of teaching, some bases for selection of curriculum material, and the thinking of "experts" show through it is only because they are a part of the author's experience. There is no real attempt at chronology. The author's professional lifetime has been devoted to the teaching of elementary science in its various aspects and this account intends only to survey some of these experiences as they relate to the total view.

TEACHING PRACTICES

In the beginning my experience was, so far as I know, a usual pattern for the time: teaching several sections of general science in grades 7 and 8. There was little science below grade 7 then. A textbook was the guide and there were few then--only one series that stretched from grades 1 to 8. Experimenting by children was mostly by receipts followed by writeups--objective, material used, drawing, procedures, results, and conclusions. Results constituted a notebook--sometimes graded, sometimes not. There was some discussion which often deteriorated into telling by the teacher. There were some firsthand experiences but they did not dominate the situations. There probably was some discovery but it also was not the overall concern.

There were a few field trips--early morning ones before school to identify birds in a nearby wood lot. Later pupils pressed flowers and mounted them with data such as common name, scientific name, number of petals, and so forth. Small wonder I wasn't fired! Simple fact: I was teaching as I had been taught during my teacher education classes at the local teachers college and testing the same way--true-false, multiple choice, fillins. Subject matter recall (facts) was the major emphasis. This emphasis and these procedures were widespread I believe in the late thirties although I am sure there were exceptions.

Teacher preparation was a "life certificate" heavy on how-to-teach courses often given by professors who would have been dropped from a public school position before the first P. T. A. meeting because of ineptness. Most had never had experience teaching children. The idea of surveying the needs of the teacher graduates was not widespread nor was there much follow-up to see what was happening to children as they passed through the elementary school. This general description may have been true only in a limited area with which I am familiar. It serves only as a point of departure in this account.

Through the years there have been many changes: in teacher education, objectives for the program, books and other materials to use, methods of instruction and evaluation. Possibly some have been chiefly for the sake of change but in the main they have been prompted by a sincere desire on the part of educators to evolve programs that would more nearly meet the needs of children and instruction methods that would bring about desirable changes in the behavior of girls and boys. We shall examine some of these changes and trends.

CHANGES AND TRENDS IN TEACHING SCIENCE

It was probably logical that early programs in science for children were more concerned with experiences with plant and animal material along with some concern for astronomy and rocks. It was in essence a nature study era. In a way its chief concern was for what the child could experience around him. There was emphasis on observation, identification, use of the senses, conservation, and appreciation. Generally the programs were not based on important research, rather on what seemed reasonable and near at hand. Then as now, although to a much greater degree, teachers in the elementary school were women who felt more at home being involved with the study of nature than in other scientific areas and the so-called normal schools where the teachers received their preparation offered courses chiefly oriented toward nature.

Personally it has always been my contention that there was much good in these nature programs. Children were urged to observe, report their findings, develop some appreciation for the objects they saw every day. Possibly there were ideas scrapped that should have been saved and used as a foundation for a broader program both in scope and intention. In some cases this is exactly what happened. In most cases it probably wasn't.

Be that as it may, the challenges of the environment and the leaders who recognized them began to expand the possibilities of science learning to include a greater variety of subject matter including more physical science material. Children's interest studies carried out by leaders in the field seemed to indicate the desirability of including such material. Along with this the objectives for the science program gradually broadened to include emphasis toward understanding big ideas in science and away from the accumulation of unrelated facts. The idea of learning how to find out--to solve problems of an important nature--followed along. An analysis of the ways scientists themselves worked in making discoveries indicated that some of these methods were appropriate to the child's way of working. These changes were very gradual in coming and emphasis on research began to seem important. Just how do children learn? What can and should they learn? What teacher education is essential and desirable for their teachers to experience? These and many other similar and important problems presented themselves, in fact still persist.

It is important to note that there was real progress in improved classroom teaching, in the preparation of books and other teaching materials, and in curriculum construction and teacher preparation long before the so-called new science came into being. Several teacher preparation institutions offered very effective courses in both subject matter and methods. State departments of education and indeed the U. S. Office of Education exercised effective leadership in curriculum construction for in-service workshops in teaching methods and other areas of science education. There was much effective activity at the local level.

Along with these activities there was a broadening of objectives for the science program in the elementary school. The teaching of unrelated facts for their own sake gave way to the development of major principles and generalizations in subject matter. There was emphasis on the development of the ability to solve science problems appropriate to the grade school and concurrently to develop scientific attitudes and interests and appreciations.

This is not to say that every school included a good science program. Many, in fact most, schools did not. Many elementary school teachers shied away from teaching science because of a low

regard for it that was coupled with a feeling of inadequacy both in subject matter and methods of instruction. Alas this is in a large measure still the case, although there have been real inroads made in the more adequate preparation of teachers for elementary school science teaching. A considerable amount of this has been focused on the teaching of specific programs that are government or commercially designed and sponsored. With the exception of these especially trained teachers there are still probably more elementary school teachers who "save science till last" (and often never get to it) than there are those who include it as a definite and prominent part of their weekly programs.

TEACHER EDUCATION

Some words about our general teacher education preparation for elementary school teachers: We consider here the preparation of the teacher who teaches science as part of her total elementary school program, not as a specialist. The general indication is that in most schools, science is still taught by the so-called regular teacher and as finances in schools become more and more limited this trend will probably increase.

One persistent problem that has bugged elementary school teachers through the ages has been their science preparation or lack of it. Generally they teach all manner of subjects and this practice still persists for most. They are expected to be specialists in every subject and each year something new manages to edge itself into the curriculum until the demand for background and skills is nearly impossible to meet. So along comes more emphasis on science teaching and a canvass of the interest in the subject among elementary school teachers would probably put it near the bottom of their list. Their own experience with science has probably been responsible.

Beginning with high school the word goes out "Don't take physics, you'll never pass it. Anyway you don't learn anything that makes any difference to you." "You'll probably hate biology; frogs are messy and their insides never look like the pictures in the book and they smell awful. Furthermore who needs to know about their internal workings."

This attitude persists when the students enter college. So the science requirements, if possible, are fulfilled by a home economics course and something from the health field. Even for those who feel brave and conscientious on registration day and sign up for Botany One regret the decision by the third day when they are assigned to memorize the Latin names of the plant classification and begin to dissect pickled seaweed. They graduate

without knowing how to raise and use living plants in a classroom or take a simple field trip around the block to observe changes in seasons. Little attempt has really been made to solve this dilemma by deciding that there must be a course that will fit teachers who are people that live in the fascinating world of plants (and other science areas) and who need to help youngsters develop some subject matter background, interest, and appreciation for this world.

Some institutions of higher learning have designed courses intended to make up for this lack of background. There have also been many attempts to bridge this gap of lack of science knowledge through the in-service workshops designed to fit the needs of the specific school systems. Unfortunately the instruction has not always been appropriate. The well-meaning high school physics teacher who volunteers to help and has his class of elementary teachers begin by winding armatures is only contributing to the problem. But fortunately there are individuals who teach in the college science department and who work with in-service groups and who are not shocked, if you will pardon the expression, by the fact that some, in fact many, elementary teachers "are afraid to touch a dry cell for fear of getting a jolt." They begin with teachers where they are, give them opportunity to experiment with materials, and gradually build a background. When they begin their teaching or return to their classrooms they experience the satisfaction of working on the same things with children. They develop a sense of security and accomplishment. The teaching of science moves forward and children's interests are broadened and they begin to learn about the fascinating scientific world in which they live.

And science teaching has moved forward. It received a shock that forced it do do so. Scarcely anyone will forget hearing the "beep" "beep" of the sputnik that opened our space travel age and upset the science teaching in the United States and elsewhere. To "keep up with the Russians" and for other reasons curricula and teaching methods were turned upside down from kindergarten to the university. More time was found for science teaching, courses were added, subtracted, altered, and shuffled. Government money was poured into projects, boxes of equipment were devised and made available, new printed material was produced. Some was good, some mediocre, some dishonest so far as value was concerned, and some never got off the ground and into the classroom. Some in-service programs for teachers were launched and colleges and universities offered science courses and workshops. Government supported projects were launched by the dozen. The elementary teachers were urged to "get the kids out of their seats, provide firsthand experiences for them, let them experiment, make time for science."

As is often the case under such circumstances much foolishness was committed in the name of science programs especially in the elementary school. In many instances school supervisors and other administrators followed the band without asking where it was going, without asking "Exactly what do we wish to accomplish with all of this?" "What parts of the present program are good and should be saved and expanded? What discarded? What is new and appropriate?" "Where do our children and teachers now stand on this road to better science education?" There were many places where *new* was confused with *better*; *more* got in the way of *enough*. In some cases individuals who know very little about children, how they learn, and what they need were in charge. Often such individuals are ill-equipped to prepare useful and meaningful curricula for children. The fact that one knows more about Mars than anyone else does not necessarily equip him to make decisions about what can and should be taught at the grade school level. There were many false starts. Much prepared material and equipment remained unused, in fact unopened, in the classrooms or was used only by those adequately prepared to make intelligent use of it.

On the other hand there were many positive results. We are, it seems, only now beginning to work out the appropriate contributions and fitting them into the total learning situations. Objectives are being refined, teaching methods reexamined, teacher education programs reevaluated. The great surge to somewhat overemphasize science has subsided and we are simmering down to a generally more acceptable place for science in the total school experience. There have been times and there still are when there is a real reaction by many laymen against science as such. Charges are made that it has been responsible for the production of harmful products and effects. Others tend to stress the beneficial results of scientific discoveries. Both points of view have influenced the teaching of science to varying degrees.

CONTENT OF SCIENCE PROGRAMS

There is still probably too much emphasis in some science programs on how to learn science and not enough on *what* science is being learned. Scientific procedures can be learned while pursuing the solving of relevant science content. This idea might well receive considerable thoughtful attention.

Some of the national evaluations would seem to indicate that our children are not as well-grounded in the appropriate content of science as they once were. In this connection, however, there are many knowledgeable educators who believe the measuring stick used to determine this leaves much to be desired. As is the case of any evaluation there are many outcomes that cannot be measured

by paper and pencil tests and in the construction of the tests there are great pitfalls in the preparation of test items especially when the evaluation is intended for use in surveying a great variety of situations.

Obviously we have come a long way from the practice of using the textbook as the total curriculum, stressing the learning of isolated facts, keeping notebooks and memorizing vocabulary and definitions. For example:

- Content has generally become more meaningful and challenging.
- The objectives are broader in scope and more specifically stated to make better evaluations possible.
- There is better coordination between various levels of learning from K-12 and beyond.
- There is more emphasis on learning how to learn.
- Various subject matter areas, notably mathematics and science, are being effectively coordinated.
- Many of the science programs are designed for <u>all</u> children from the brightest to those with limited abilities and skills. In this connection there are conscientious attempts at individualizing instruction.
- There is more intelligent work in curriculum construction involving all who have an interest in the result and the responsibility for carrying it forward.
- The printed material, apparatus, and other teaching aids have vastly improved in quality and appropriateness.
- There is much experimental teaching that helps us come closer to a better basis for decision making about content selection and teaching procedures.
- More teachers are teaching better.

With all of this there are some specifics that all concerned need to keep in mind for the future: It's what happens to children in the classroom that counts. No matter how carefully the objectives are stated and restated, unless they are translated into reality in the classroom they serve little purpose. There is still much that takes place in classrooms that is nonsense because it is not related to our purposes. It's quite possible to teach as badly with mystery powders and mealworms as it is with using air pressure to force hard boiled eggs into milk bottles. Activities of any kind are boondoggles unless the teacher *and children* understand their purposes and proceed accordingly. No child nor adult can learn everything from firsthand experiences. Reading is still an important source for accomplishing our objectives. There are still probably as many, perhaps more elementary teachers who have real difficulty with science teaching as there are who feel at home with it and do an effective job. This means that thousands of children are still

deprived of a good start toward understanding the science world in which they live. This should make us all pause to think and use our talents and skills wisely toward improvement. Even for children there is so little time.

Donald G. Decker was born in 1914 in Colorado. He received his early education in Michigan schools after which he attended Michigan State Normal College (now Eastern Michigan University) where he received his B.S. in 1935. He was awarded his M.A. from Colorado State College of Education (now the University of Northern Colorado) in 1937 and his Ph.D. from Teachers College, Columbia University in 1943. In 1951 he was awarded an honorary Doctor of Science from Eastern Michigan University.

Dr. Decker taught in the campus laboratory school of Colorado State College of Education from 1937 through 1939, when he joined the Bureau of Educational Research in Science at Teachers College, Columbia University. He remained at Teachers College until the completion of his Ph.D. in 1943, although the 1942-1943 year was on special assignment with the Tennessee Eastman Corporation, Manhattan Project at Oak Ridge. Dr. Decker joined the Faculty of Colorado State Teachers College as an Assistant Professor of Science Education in 1944 where he remained until health forced him to retire in 1975. He was promoted to Associate Professor in 1944 and to Professor in 1946. He served as Chairman of the Science Division from 1950 until 1955 and Dean of the College of Education from 1955 until 1965. Dr. Decker was appointed Provost of the University in 1966 and Dean of the School of Educational Change and Development in 1970.

Dr. Decker has been active in professional organizations, including NSTA, NARST, AETS, AAAS, and the Colorado-Wyoming Academy of Science. He served as member of the board of directors of the Colorado-Wyoming Academy of Sciences and on the Earth Sciences Curriculum Project. He served as president of the Colorado Science Teachers Association in 1944 and president of the National Science Teachers Association in 1959-1960.

Dr. Decker authored and coauthored over one hundred science textbooks and manuals for grades one through nine. His articles have appeared in many education and science education journals. He has served as a collaborator, author, and reviewer for various audio-visual productions and popular school publications.

Dr. Decker was honored by the International Institute of Arts and Letters for his service. Sigma Phi Epsilon fraternity presented him with a Distinguished Service in a Chosen Career Award in 1973. He was honored as Professor of the Year by the University of Northern Colorado in 1975.

FORTY YEARS OF BECOMING, BEING, AND BEGONING:
AN ACCOUNT OF A PERSONAL JOURNEY
INTO THE SCIENCE EDUCATION OF
STUDENTS AND TEACHERS 1936 to 1976

DONALD G. DECKER

Professor Emeritus of Science Education
University of Northern Colorado
Greeley, Colorado

How does one organize a lifetime of memories? How does one, retired at the age of 61, react to what he wrote and said 40 years ago and each year since that time? To rediscover your immaturity is somewhat embarrassing but to recapture a historical series of events in science education is exciting. Please do not assume that everyone will agree that this is what actually happened or that others thought it important to happen. It is my perception of what was happening and should happen. Others will have a much different interpretation of what actually happened and this will be the excitement of this yearbook.

INTRODUCTION

In reviewing my 40 years of experiences in science education I have come to three basic conclusions:

1. Education is no different from any other facet of our culture. In society, as well as in education, the battle of the individual and society, at the moment, rages onward in an effort to determine who shall rule whom, how shall it be done while maintaining our concept of democracy, and determining how education and society best function, now and in the future.
2. Teaching is no different from any other facet of our culture. The battle of the teacher and the administration, at the moment, rages onward in an effort to determine who shall rule whom, how shall it be done, while maintaining our concept of the teaching profession and determining how teachers can function most effectively.
3. Learning is no different from any other facet of our culture. The battle of the teacher and the student, at the moment, rages onward in an effort to determine who shall rule whom, how shall it be done while maintaining our concept of individual differences and determining in what learning environment individuals best function.

But let history speak for itself. What follows are excerpts from speeches given over four decades. They are organized as a personal historical account into six sections and ten generalizations:

I. THE WINDS OF CHANGE BLOW GENTLY

- Change science education. Each teacher of science should be knowledgeable of the total science education of the students.

II. FUTILE GESTURES ARE MADE

- Coordinate the study of science. Choose significant and practical themes.
- Come to grips with our own beliefs, attitudes, and prejudices in the areas of controversial topics.
- Educate about what is happening now.

III. SLOWLY THE INDIVIDUAL ARISES FROM THE MULTITUDE

- Know the individual. Know his concerns and his needs.

IV. THE GREAT PROCLAMATIONS

- Improve the science curriculum.

V. TOGETHER WE STAND

- Rely on scientists for directives in science curriculum improvement.
- Promote the objective of literacy in science.

VI. THE TRUMPETS SOUND

- Develop coordinated, well-planned, and structured programs from kindergarten through the 12th grade.
- Contribute a visualization of science education K-12.

SUMMARY

- Promote revised changes in science education as science and society change.

I. THE WINDS OF CHANGE BLOW GENTLY

Change science education. Each teacher of science should be knowledgeable of the total science education of the students.

During the 1940s the social significance of science was being debated. In 1944 I made a speech in rebuttal to a set of proposed objectives for science teachers.

"If science teachers have but one aim--to teach subject matter--they have no socially significant aim. Any aim that is not socially significant is worthless. Operating with a pattern devoid of social significance is producing science students who work without social objectives and without social accomplishment.

"Change is necessary. We should educate science students so that they develop a sense of social values as deeply rooted in them as is their scientific knowledge, who work to make their special competence a contributing factor in the achievement of those values which belong within a democracy. If teachers believe that power should reside within the individuals of a democracy then they must teach for inquiry, discovery, and application.

"To intimate that teachers should withhold their social values from their students is to place our confidence in those less worthy of opinionating students. For scientists and science educators to accept a neutral position in our culture is to intimate that their intellect and education lack tangibleness in the lives of people, lack the essential accompanying sense of social values, and lack a social frame of reference which would make their endeavors worthwhile."[1]

In 19?9 I talked about the social significance of science. I believed that the end of World War II and the atomic bomb had forced a dramatic realization of the impact of science on societies.

"As teachers you should understand the full significance of this age that was initiated in the violence of modern warfare--an age that welded forever in the consciousness of people the inevitable relationships between scientific knowledge and their social affairs.

"The atomic age babies you will teach will not remember the beginning of the atomic age. You must recreate the events that produced the knowledge that enabled us to use atomic energy. You should ask an important question. Have the predictions made after World War II become realities?

"The predictions:

"1. Human beings now know how to destroy the human race.
"2. Rockets in five years will speed a ton of mail across the Atlantic in 40 minutes.
"3. The fuel tanks in cars will be replaced by a builtin fuel supply for the life of the car.

"4. Roadside gasoline stations will disappear.
"5. Oil as a fuel will disappear.
"6. Coal mining as an industry will cease.
"7. Our atomic knowledge guarantees 100 years of peace."[2]

We are now educating the second generation of World War II babies and a comparison of the above predictions with the realities of actual events is almost ludicrous. Perhaps we have ceased to stress the social significance of science as a means of using our scientific knowledge for the betterment of society. It is terrifying to realize that in 1976 only one prediction is a reality--human beings now know how to de roy the human race.

For more than 40 ye the science curriculum has remained basically unchanged. Reflect on the science curriculum now in your own school system as I review for you the current curriculum patterns in science.

"The intellectual climate in the primary grades in science is as variable as the combined climates of the polar regions and the equatorial regions. In some primary grades practically no science is taught. The science climate is cold and barren and suggestions for well-organized programs are met with the chill winds of the polar climate. In other primary grades science is well organized and well taught. The science climate is warm and lush and suggestions for improving programs are met with the warmth of equatorial winds.

"The intellectual climate of the intermediate grades is somewhat like the temperate zones with four seasons. Suggestions are considered and more science is taught, although much of it is restricted to the 5th or 6th grades. The curriculum deals too seldom with the current knowledge that students have acquired from their cultural environment outside of school and . often with the odd knowledge the teacher 'picked up' in summer school. Elementary students know more science than we give them credit for and they can learn more science than we give them an opportunity to learn.

"The intellectual climate of the junior high school is like the doldrums of the oceans. An informal study of 36 junior high school programs, topic for topic in science, revealed that the same topics are taught in each of the three grades--7th, 8th, and 9th--and they are many of the same topics taught in elementary school. Without a designation you could not identify one grade program from another. The intellectual climate of the junior high school is not built on the previous experiences of the students and their elementary school science programs or lack of them.

"The informal study of the 36 junior high schools revealed that the study of fossil life was a topic in 50 percent of the 7th grades, 43 percent of the 8th grades, and 85 percent of the 9th grades. Food making in plants is taught in 86 percent of the 7th grades, 57 percent of the 8th grades, and 85 percent of the 9th grades. Weathering and erosion is taught in 64 percent of the 7th grades, 76 percent of the 8th grades, and 92 percent of the 9th grades. The use of simple machines is a topic in 14 percent of the 7th grades, 79 percent of the 8th grades, and 85 percent of the 9th grades. Production and use of magnetism is a topic in 57 percent of the 7th grades, 71 percent of the 8th grades, and 92 percent of the 9th grades. Characteristics and uses of water is a topic in 64 percent of the 7th grades, 57 percent of the 8th grades, and 76 percent of the 9th grades."

The K-12 program, its present status:

"A study by Patricia Blosser of the science backgrounds of 226 students in required 9th grade science revealed that about one half of them had had no elementary science in grades kindergarten through the 6th grade (1). About one half of them had had some elementary science but most of this group had not had it in kindergarten through the 4th grade but in grades five and six. Seventy-five percent of the students had had no science in grades seven and eight. Twenty-five percent of the students had had science in grades seven and eight.

"This means that half of the students started 9th grade science with no previous formal education in science; a rather weak foundation in the twentieth century. The 9th grade teacher must surely have been a master teacher to combine the past experiences of this diversified group into a well-organized 9th grade program that provided for the individual differences resulting from the variety of backgrounds of these students.

"One year of science is required for graduation. For some students the 9th grade science course will be a terminal course. Other students may elect biology, chemistry, or physics and if the pattern is true for this school, large proportions of them are likely to elect them in that order.

"As you think about the program described by Miss Blosser compare it with the recommendations for a science program adopted by the National Association of Secondary School Principals (NASSP) in 1958 and I am sure you will recognize the need for a careful study of the K-12 science program.

'1. Programs in science should be developed and carried on as a part of a continuous program beginning in the elementary schools and extending through the senior high school.

2. Science study in grades 7-8-9 should build upon the program of science in the elementary grades. All normal pupils in grades 7-8-9 should be encouraged to study some form of science in each grade.
3. Schools should update their science programs to adapt to the technological facts of everyday living.
4. The curriculum must change in response to changes in our culture' (3).

"Permit me, if you will, to give as an example a school moving to implicate these recommendations. The public schools in Greeley, Colorado, for more than five years have had vertical committees of subject matter teachers planning a K-12 program in all areas of science in cooperation with horizontal committees of teachers by grade levels. Now science is required in kindergarten through the 6th grade and in the 7th through the 9th grade making a firm foundation for a K-12 science program. Biology is also required of each student. Chemistry, physics, and advanced biology are elective. In this school system of 5,750 students 11 years of science are required. The committees are constantly at work reviewing, adding to, and improving the program with the overall objective of developing what they consider a good K-12 program.

"The K-12 program is not a new innovation or a new movement in science education. It is not a program which means starting afresh and building over. It is a program that urges the review of the existing program in each school and a filling of the gaps where the program is not of the quality that it should be. This is a task for each individual school and community. It urges the keeping of those parts of the program that are functioning well and are serving their purposes in education but it does mean eleminating those parts of which this is not true and inserting new parts in these places.

"The intellectual science climate of the senior high schools is like the desert, dry and unchangeable. The sand dunes of biology, chemistry, and physics shift back and forth, rearranging themselves but basically never changing. The possibilities of adding new courses such as geology, astronomy, meteorology, and an understanding of technology (the application of pure science to industry) are rejected with firm convictions of prejudiced opinion rather than consideration of the abilities and interests of the students. Thousands of students will enter administration, civic responsibilities, and all kinds of vocations in which, in the future, it will be most imperative to have an understanding of what the current scientists are talking about.

"The intellectual climate of our science programs has been one of satisfaction, of limited opportunities for the study of the sciences, of limited opportunities for growth, and limited planning by science teachers to coordinate science programs in their school systems from kindergarten through grade twelve. Many teachers are still convinced that the rearrangement of existing topics, courses, and subject matter is the key to improvement."[3]

"A few weeks ago I visited the Wax Museum in Washington, D.C. I stood silent and in reverence in front of the wax figure of Albert Einstein. There is not a book, a pencil, a folder, a tablet, or a blotter on the desk behind which he sits. On the wall behind Einstein is a small blackboard with only one mark on it, $E = mc^2$. The impact of the entire display forces you to think of two words, teacher and thinker. The wax figure of the world's greatest scientist sits without test tubes, laboratory equipment, or science apparatus of any kind. Associated with him are only ideas of great quality: the new concepts he contributed to science. We need a creative Einstein in science education to ask and to find answers based on new concepts."[4]

II. THE FUTILE GESTURES ARE MADE

Coordinate the study of science.
Choose significant and practical themes.

Throughout the years attempts have been made by various individuals and organizations to improve science education by selecting science content that is coordinated by significant and practical themes relative to science and its contribution to a better world. Samuel Ralph Powers of Teachers College, Columbia University, was one of these individuals. He firmly believed in the late thirties and the early forties that there was a possibility of improving science education to make it more significant in the lives of science students and an important social agent in society. He gathered about him scientists and young science educators to develop a series of materials that would be quite different from any on the market at the time.

In 1942 I listed in a speech nine problems the group was studying.

"The Problems of a Better World:

"1. How can biological production be used to establish, promote, and maintain a better world?
"2. How can personal and public health be maintained in a society?
"3. How can the control of organisms be maintained in a society?

"4. How can an understanding of the human life span be used to promote a better world?

"5. How can an understanding of the variation among living things contribute to making a better world?

"6. How can an understanding of the interrelationships of living things contribute to a better world?

"7. How can the production, distribution, and consumption of materials be improved to contribute to the forming of a better world?

"8. How can the transformation and utilization of energy be improved to promote a better world?

"9. How can an understanding of the nature of the earth and universe contiibute to promoting a better world?"[5]

The materials the group wrote were never published. Some of the resource materials that various scientists had written were published. Although the majority of the problems remain in 1976 as major problems in the world, the ideas originated in 1942 for some reason never "caught on." I am sure they did make a difference in the thinking and the teaching of those who worked with Dr. Powers but an honest appraisal of the impact of the ideas after more than 30 years is that the program of which Dr. Powers was the director--the Bureau of Educational Research in Science--was one of the futile gestures in science education.

Come to grips with our own beliefs, attitudes, and prejudices in the areas of controversial topics.

Throughout the years many futile gestures have been made to improve the teaching of science and the science curriculum. They were made by individuals and organizations who were sincere in their belief that their plans and suggestions had merit and would appeal to administrators, science curriculum committees, and science teachers. One of the most difficult questions to answer is how do innovative ideas and suggestions for change become a part of the total pattern of science education? Who is successful in preventing change in science education? Why is change relatively easy to introduce in elementary science and so difficult to introduce at any other level of science education? In 1976 communities are still debating as they were 50 years ago the teaching of sex education and evolution.

In 1949 I was speaking in favor of sex education in the science curriculum.

"It is interesting that an area in which we do so much thinking from puberty to death is one we know so little about in education.

"We cherish our errors to such an extent that we are willing to perpetuate them. Knowledge is no criterion of behavior but we organize subject matter specifically to eliminate concepts that

might be identified as sex education. The greatest obstacle is the attitude of adults. Improvement must first occur in the minds of the teachers, in their attitudes, beliefs, opinions, and feelings.

"We allow children to tramp around on the fringe of acceptable adult social behavior long after they cease to be children biologically. We are peculiarly amazed when they adopt unacceptable standards for their social behavior. We are properly awed and maliciously gossipy when the natural consequences of their acts occur.

"The collection of desirable experiences is the obligation of the school. To make this selection teachers must appraise and analyze the individual, society, natural forces, and the learning process to determine, uphold, and verify standards of social behavior which will culminate in stimuli more forceful, permanent, and desirable for the direction of individual behavior than the multistandard confusion of values which we now accept and promote with such nonchalance and ignorance of its effects on youth and adult alike."[6]

Educate about what is happening now.

In 1950 I addressed an audience concerning the neglected areas of energy and power in the science curriculum. I now classify it as a futile gesture.

"I sometimes discover that I have neglected entire areas of subject matter--topics that are important to children and ideas that are vital to this generation--because I have allowed myself to forget that as an adult, living in this century of science, I have a special responsibility to my students: to help them acquire a series of experiences that will prepare them for an understanding of a world when they move from childhood into youth and from youth into adulthood.

"You and I and the children we teach were present in the world when the atomic age exploded about us. Did we immediately incorporate it into our science curriculums? No, we waited for it to appear in science textbooks.

"We are content to let the radio, the comic books, the magazines, and the television programs instruct our children in reference to atomic energy. We have done so little to bring into our schools the filet mignon of living in the twentieth century. We would rather dust the dust from the coffins of knowledge that were buried centuries ago and pull forth some old cobwebby ideas that affect no one today and spend our time on topics that children are only too happy to bury as soon as they leave school. How many years have we taught and demonstrated the three kinds of water wheels?

"Atomic energy is a concept that demands much understanding and much working together as teachers to develop concepts for each grade so that children don't have to learn everything at once when they get to high school.

"The use of power in reference to muscle power, wind power, steam power, the power of exploding gases, electrical power, and atomic power is essential fo an understanding of man's development of his power resources and it is an easy way to help students understand the place of atomic energy in the history of man's use of power. Students are able to understand the similarities and the differences among the kinds of power that man uses and the sources of these powers. More important still is the student's conception of the possibility of the uses of these powers.

"The greatest mistake we can make is to teach atomic energy in each grade. We have done that with health until the idea of health is almost revolting to students. An informal questionnaire revealed that the one activity students would like to have only once was drawing a tooth. Guided by student questions, directed by their interests, stimulated by current events and our own conception of what is happening, we can achieve in this new field a directed and coordinated curriculum instead of the hit and miss proposition that we have had in science previously.

"We are likely in education to make a fad, a movement, a cause out of every new idea. Do you recall the feverish emphasis we placed upon aviation education? Everywhere teachers were urged to translate mathematics, spelling, reading, physical education, science, social studies, and all other subjects into activities significant to the understanding of aviation as though all students were to be aviators or live in an age of air travel without ever touching their feet to the groun [7]

Another neglected area in science education I tried to emphasize in 1950, which was also a futile gesture, was the study of the community.

"The teacher who conceives the community in which he is teaching as a group of living things in a physical environment will interpret that community to his students in a much different way than a teacher who does not have this conception. The teacher should see the community as a place in which air and water, and energy and materials, constantly flow through that community and make it possible for life to exist or not exist.

"Such a teacher is concerned with raising questions in the classroom such as:

"1. If all life was removed from this community what would remain?
"2. How has man changed this community?
"3. What ideas in science have made it possible to change the community?
"4. Who can name the things that man has placed in this community that wouldn't be here unless he was here?
"5. Have the things that man has brought into this community been a benefit or a detriment to the natural community?
"6. How can we make a scientific evaluation of our community?"[8]

I tried to be more specific about teaching for understanding of the community in another speech in 1950.

"Scientific facts can be used to describe the community to primary grade children, to explain the community to junior high school students, and to predict the future of the community to secondary school students. A scientific description of a community includes the materials and energy that are available for use in the community. A scientific explanation of a community tells how these materials and energy are used. A scientific prediction about the community reveals how the results of the way the materials and energy are used will effect the future of the community.

"Students should recognize the difference between a natural and a social community. They should understand that natural communities can exist without man in them. And they should understand that when man becomes a part of a natural community the flow of energy and materials is changed. They should also understand that the flow may be beneficial or detrimental to the natural and social community.

"Students should also know that when living organisms (plants and animals and human beings) are added to a community more materials and energy must be supplied to the community. An increase in the number of living organisms increases the amount of waste that must be carried away from the community.

"The evaluation of a community can be made by determining the purity of its water, the methods of disposing of waste, the health of its people, the ease with which work can be done, the amount and kind of transportation supplied, and the amount and kind of communication provided."[9]

Another futile gesture of mine in an attempt to suggest significant and practical themes to coordinate the study of science was my attempt to encourage science teachers at all grade levels to consider including in their science curricula a study of the life spans of plants, animals, and human beings.

"All organisms live through a life span. No topic is of greater, continual, general, and genuine interest than the topic of the life span. Each person is having an experience with one part of it. It answers the questions: What happens as organisms grow and develop? And, what happens to me as I grow and develop?

"With each different stage of the life span the personal exchange of materials and energy from the environment changes. The expressions of desire and frustration change and are controlled and used for different purposes. A study of the characteristics of each part of the life span helps one to understand what is in the future for the person and what has preceded the present experiences.

"The study of the life span enables one to visualize an organism in relation to its environment as the study of the community helps one to visualize the relation of community activities to individual organisms.

"It is important in an interpretation of living things to discover the common characteristics of all life spans from the protozoa to mammals. The topics of food, elimination, metabolism, nutrition, health, accidents, recreation, attitudes, beliefs, and responsibilities can be included in the topic of the life span.

"Important social application such as the control of insects, disease, and microorganisms depends upon an understanding of the life span of these living things. In the primary grades the care and feeding of pets, the hatching of eggs, and health habits are all topics that can be woven into the fabric of a study of the life span. In the intermediate grades information concerning the functioning of their own bodies, control, responsibility for the adjustment to factors that affect their bodies, the care and feeding of pets, and other similar topics can prepare students for the important topic of body changes in the junior high school.

"Materials for the study of the life span are continually all about them. The relationships of many scientific facts are easy to show in the study of the life span. Many times new activities are not needed in the science class but a new purpose and a new emphasis are important in the building of better attitudes about students themselves and the world about them."[10]

Another most pitiful futile gesture in science education has been the teaching of conservation. In 1953 I suggested three questions teachers should answer before beginning conservation education.

"1. What concepts about conservation are important for students to have?
"2. What concepts about conservation education are important for teachers to have?
"3. At what grade levels should conservation concepts be taught?"[11]

The mammoth pollution problems existing on this planet in 1976 emphasize the futile gesture of educators to try and prevent through education the conditions that now surround us and the problems that now must be solved for survival to be a reality.

In 1965 I was again futilely suggesting a new approach to curriculum renovation in the junior high school.

"Our culture today is composed of basically two kinds of knowledge:

"1. The knowledge man has discovered--science.
"2. The knowledge man has created--technology.

"The two are intricately interwoven in the activities and the affairs of man. This is the world of the twentieth century in which students are living and will live. This world concept, emerging for the last 50 years, is one result of a growing understanding of the universe as a matter-energy system. An awareness and a partial understanding of this system should be the foundation upon which physical and space science are taught and learned at the junior high school level. It is also important for the teaching of life science at the junior high school level.

"The broad and comprehensive image of the important relationships existing in this matter-energy system and man's application of these ideas for the production of goods and services produces a fitting and desirable background for his study and deepening understanding of the specialized sciences at the junior high school level.

"This broad and comprehensive image is also important to an understanding of the basic productive activities of man in his communities. Industry, agriculture, communication, and transportation are based on an understanding, a control, and a predictive calculation of the energy and materials needed for a system to produce goods and services for the use of people. In the universe, in a community, in the human body, in the technological industries the

input of materials and energy is necessary to produce an output of materials and energy in the forms of goods and services required for daily living in the twentieth century."[12]

In 1960 I was pushing for a reorganization of the curriculum in the elementary school. My basic thrust was to get away from the fragmented, topical approach to elementary science and to coordinate the program by introducing basic themes of scientific, individual, and social importance. I suggested five themes:

"1. The Human Body; Its Growth and Development.
To me one of the most neglected areas of study of tremendous interest and importance to the individual is the human body. The curriculum includes hygiene, anatomy, and physiology and with the exception of the late thirties and early forties practically no emphasis upon sex education, mental health, boy-girl relationships, marriage, and an understanding of the adult and the period of senescence.

"2. The History of the Earth; Its Changes and Future.
Most of the teaching is confined to dinosaurs, weather, volcanoes, and the solar system, with now and then an inclusion of the concept of the galaxies. The sweep and magnificence of the full history of the earth and its future is largely neglected.

"3. The Cycles in the Life Zones; Photosynthesis, Nutrition-Respiration, and Putrifaction-Decay.
Photosynthesis, nutrition, and respiration are taught during a study of plants and the human body. The life zones are generally neglected and the cycles in them that produce evolving communities, eventually reaching their climax state, are neglected.

"4. The Organization of the Universe; Its Forces, Objects, and the Exploration of It.
The planned exploration of space has been largely neglected in elementary science, although familiar objects are overtaught. Very little is included in reference to the forces operating in the universe.

"5. The Scientific Evaluation of the Community; The Impact of Science on Community Living.
Practically nothing has been included in elementary science to help students evaluate how good their communities are in reference to the flow of materials and energy, transportation, agriculture, and industry."[13]

It is interesting now in the late seventies how important topic 5 has become since pollution has finally become a major problem.

III. SLOWLY THE INDIVIDUAL ARISES FROM THE MULTITUDE

Know the Individual. Know his concerns and his needs.

In the thirties much of the attention of the educational community was focused on the individual in the classroom and methods of teaching for individual differences.

In 1939 I asked teachers to consider individuals in their classrooms.

"How do you conceive your role as a teacher? Your conception of it will determine the quality of the educative experience of the children who are associated with you as a part of their education.

"As a teacher you can squash and humiliate the personality structure or you can challenge and invigorate it. Which do you do?

"There is no defensible goal of education other than the freeing of the individual intellect to pursue ideas of interest and immediacy to him.

"Education consists, for the teacher, of the permanent excitement of viewing and predicting what an individual may become when freed to become that of which he is capable."[14]

In 1950 another method of handling individual differences was introduced: science clubs. I addressed myself to this topic.

"Many times we do not challenge students so that they have to think beyond what they already know and we wonder why they become bored and uninterested in the work they are doing.

"It is important to have a well-organized program in which there is provision for experiences that will help children learn certain basic science facts and principles each year.

"Growth has been defined as increase in size and bulk. Many of our science programs are of a similar nature. We increase the size and the bulk of the science facts that students are to learn without reference to previous learnings or eliminating anything from the programs.

"A science curriculum should change in function as children mature. The same ideas do not need to be retaught but their application should be related to experiences of children at different maturity levels. Their scientific knowledge will function differently as they grow and develop.

"Many teachers do not like to deal with the common knowledges of students because the teachers' interests in the scientific world ar narrow. Students often ask questions teachers cannot answer. Students ask questions that do not fit into any scheme of organization the teacher had planned. Often questions put teachers the spot. Most teachers agree that if they felt secure in hand these situations, that these experiences would be desirable.

"The is also a danger that an entire science curriculum may become random in nature with no organization if students are not trained to evaluate their questions and their experiences as to their desirability for class discussions and study.

"Many eachers have bemoaned the fact that students are actively interested in science clubs and they wish that they could get the same interest in science classes. In science clubs students often organize their activities and projects that are of current vital interest to them. These extracurricular activities are often more functional in the lives of children than are the regular formal activities in the science classroom. Why not use science clubs and their topics as curriculum take off points?"[15]

In 1950 I made what at the time I thought were most profound statements about science education.

"1. The limitations on individuals imposed on the educative process by its designers are the fundamental threats to the energizing forces for change in any culture.

"2. The conceptualization of what an individual can become through education is as important in the educative process as the understanding of specific concepts in each discipline.

"I am sure you remember the tremendous emphasis on problem solving--a method by which the individual was allowed to state the problem he wished to study, plan how he would solve it, and become the major factor in its solution. The interests, needs, and concerns of students became a fundamental issue in education; John Dewey was the accepted educational philosopher. The Progressive Education Association (PEA) flourished.

"When process becomes the directive for learning content, the content is limited to the successful manipulation of the process and education becomes the art of the practitioner rather than the development of the individual.

"3. A philosophy of education is as important in the educative process as the understanding of specific concepts in each discipline.

"Throughout these decades three distinct camps waged war among themselves. The authoritarians constructed curriculums by accepting values from external sources. Content, they said, should be determined by scientists, process is the experiencing of content, and children should learn what scientists know. The laissez faire concentrated on the individual and his growth and development. His source of values was the individual. The experimentalist's source of values was experience."[16]

In 1958 I was speaking on the different approaches to the science curriculum in the elementary and secondary schools and their impact on the individual learner.

"We have two basically different approaches to the curriculum of science in the 12 years of a child's life in the public school. The first six years are dominated by the idea that the curriculum must be molded to fit the maturity of the learner. The last six years are dominated by the idea that the learner must be molded to fit the subject of science he is studying. These two incompatible concepts of curriculum making in science are the reasons that we have a problem concerning the role of science in the American public school system

"The great advances in science curriculum building will not come from the collection of new organizations of existing science curriculums but from the development of new concepts of what the K-12 science curriculum should be."[17]

In 1963 I adapted some ideas I had learned from John Lawrence Childs of Teachers College, Columbia University in 1942. He had lectured about his ideas of the four levels of learning. I tried to adopt his ideas to help teachers see the students in their classes in a new perspective.

"The first level of learning. (Hold up a partially rusted half gallon tin can.) This can is responding to the imbalance between itself and its environment and it is modifying itself as it learns. It is rusting away. It is combining itself with its environment and when the rusting process is complete there will be no can and a balance will have been achieved between the can and its environment.

"You may have students who remain at this level of learning and rust away intellectually. They respond to their environment in the classroom automatically with the abilities with which they were originally endowed as human beings. The imbalance of the oxygen and carbon dioxide mixture in their lungs forces them to try and maintain a balance. They breathe unconsciously, as the tin can rusted unconsciously, and they remain alive in the classroom but that is all.

"The second level of learning is the response level. (Hold up a mimosa plant.) This level of learning is like the mimosa plant. It adjusts to certain stimuli in its environment. As I touch the leaves of the plant they fold. In a short period of time they will reopen. Response and adjustment take place in this living organism. It is a low level of learning because the response is always the same. Some teachers treat their students as though they were mimosa plants. All they expect students to do is memorize what they are told to memorize and repeat it back when the proper stimulus is given by the teacher.

"The third level of learning is called the problem-solving level. A monkey not only responds and adjusts to the imbalance in his environment but he attempts to solve problems and change conditions to better suit his purposes. This is the level of purposeful learning; the level at which learning now is effective for living tomorrow. Those of you who teach by the problem-solving method are introducing the concept of purposeful learning to your students and skills that are effective in their future life.

"The fourth level of learning is called the creative level. Man has distinguished himself with a mark of genius by creating ideas as significant as the conceptions of space, time, matter, and energy. Teachers who identify students who are able to operate at the creative level of learning and make it possible for them to do so contribute to the great reservoir of creative ideas from which one day new concepts may emerge. Few of the geniuses of the world attribute their creativity to the stimulation received from their teachers."[18]

IV. THE GREAT PROCLAMATIONS

Improve the science curriculum.

In 1962 I listed some of the great proclamations made in American education throughout the years.

"In 1910 science was conceived as a service for the improvement of the activities of men as were all subjects in the curriculum. The Seven Cardinal Principles of Secondary Education were to be the directive for the organization of science and other subjects in the junior and senior high schools (2). Courses of study consisted of selected subject matter that would emphasize health, command of fundamental processes, worthy home memberships, vocation, citizenship, worthy use of leisure time, and ethical character.

"Do you remember the great proclamation--children must not lose contact with nature? The impact of urbanization concerned Anna Botsford Comstock. She wrote the *Handbook of Nature Study* (4) and Cornell University published the *Cornell Rural School Leaflets* (5).

Both publications emphasized nature study, not elementary science, as a means of perpetuating the agricultural society as opposed to the industrial society. Industry was an energizing force for change.

"Do you also recall the great proclamation--children can learn science by reading? Thirty years of nature study were finally made a part of the reading program and the first nature readers appeared on the market, written by Edith M. Patch and Harrison E. Howe (7), and Ellis C. Persing and Elizabeth K. Peoples (8)."[19]

"The 1932 National Society for the Study of Education (NSSE) yearbook emphasized the development of learning exercises around broad principles of science which are fundamental to the understanding of science (6).

"This yearbook became the bible for the science educator but the emphasis was quite different from the Seven Cardinal Principles of Secondary Education."[20]

This was a recurrent theme in my talks for in 1949 I said, "Another great proclamation was made by the PEA movement that placed emphasis on four areas of living for the purpose of the adjustment of the individual. All areas of the curriculum were to organize curriculums to emphasize the four areas:

"1. Self-personal.
"2. Home and family.
"3. Community.
"4. Economic relationships.

"Attempts to organize a science curriculum to emphasize these areas was almost disastrous. I remember clearly working on a state course of study that organized the science curriculum in this manner. It was never published.

"I was also engaged for many years in a reorganization of the junior high school curriculum to be called Unified Studies. The basis of the program was problems concerning individuals and groups, getting along well with others, following plans and directions, using the problem solving method.

"The 7th grade students studied the improvement of personal appearance, the influence of the home on behavior, the influence o beliefs on behavior, and the improvement of learning. The 8th grade students studied transportation, materials and energy (our resources), agriculture, industry, and communication. The 9th grade students studied selecting a vocation, characteristics of the population, and the changing earth.

"The idea was never popular with the public schools and it became another one of the futile gestures in the improvement of science education."[21]

The High School-Life Adjustment Program was another program that died a quiet death (11). It was sponsored by the federal government. In 1949 I was explaining the program to science teachers.

"Life adjustment education is defined as that which better equips all American youth to live democratically with satisfaction to themselves and profit to society as home members, workers, and citizens.

"The objectives of the program are:

"1. Ethical and moral living.
"2. Citizenship.
"3. Home and family life.
"4. Self-realization.
"5. Use of leisure.
"6. Health and safety.
"7. Consumer education.
"8. Tools of learning (number, language).
"9. Work experience.

"There is a great question in the minds of many science teachers as to the suitability of these objectives for science education. Many teachers believe the suggested objectives have always been the objectives of the social studies curriculum and that it is the responsibility of social science teachers to make this program effective."[22]

V. TOGETHER WE STAND

Rely on scientists for directives
in science curriculum improvement.

In the sixties I returned again to the statements scientists were making that should have a profound effect on science education. Among them were:

"I once listened to Carl Gustafson talk about his research involving the internal secretions of the body. I was thrilled to hear this great man explain his problems, his work, and his findings. This spring I listened to Dr. Gustafson again. I was prepared to hear about the recent research in his field of science. This I did not hear.

"I heard an impassioned plea for scientists to work for peace. He documented his plea with scientific facts relating to materials and energy and needed research. He pleaded with us to drill into our students the great social responsibility scientists have to direct their research toward peace. He asked that this be a purpose of science.

"Scientists and science educators are speaking a similar language. Together we stand for socially significant purposes in science and science education."[23]

"The present status of science in our culture is most realistically described by C. P. Snow in a magazine article (10). He asks this question:

> 'Have we begun to comprehend even the old industrial revolution, much less the new scientific revolution in which we stand? There never was anything more necessary to comprehend.... Out of the industrial revolution grew another change, closely related to the first, but far more deeply scientific. This change comes from the application of real science to industry. I believe the industrial changes involving electronics, atomic energy, and automation are in cardinal respects different in kind from any we have experienced before and will change the world much more. It is this transformation that, in my view, is entitled to the name of *scientific revolution*. This is the material basis of our lives, or more exactly, the social plasma of which we are a part. And we know almost nothing about it.... Why aren't we coping with the scientific revolution? If one begins by thinking only of the intellectual life or only of the social life, one comes to a point where it becomes manifest that our education has failed us....'"[24]

"One of the finest quotations in reference to the goals of science, I believe, was made by Lee DuBridge.

> 'Science will be judged not by how fast it helps us to travel, but where it helps us to go.'"[25]

Promote the objective of literacy in science.

"Harlow Shapley wrote,

> 'As we used to hold in significance the alphabet of language, today science has progressed to the place where alphabets have been developed that represent the accumulated knowledge--classified, and verified, and expandable--with which one thinks basically in science.
>
> '1. The periodic table in which matter is classified.
> '2. The electromagnetic spectrum in which energy is classified.
> '3. The geological timetable in which time is classified.
> '4. The classification of space in which the material systems, electrons to galaxies, are classified in order of size or mass'" (9)[26]

VI. THE TRUMPETS SOUND

Develop coordinated, well-planned, and structured programs from kindergarten through the 12th grade.

In 1955 I was beginning to promote vigorously the concept of a K-12 curriculum.

"Science education has two aims:

"1. To teach students the facts and principles with which a scientist thinks.
"2. To teach students how a scientist discovers these facts and principles.

The training of a science teacher involves training for the understanding of the facts and principles and the method of the scientist.

"The acceptance of these ideas can determine the program in science in the public schools. The science educator has the task of selecting facts, principles, and experiences for each grade level which is part of the science program. The organization of a science program based on the facts and principles of science presents the problems of selection and grade placement.

"The science program in the public school should be a cumulative program from the kindergarten through the 12th grade. It should be organized around the principles of science. In each grade students should have the opportunity to learn and to have experiences with science. Each grade should have as a part of its program definite concepts that are taught to help students understand a principle of science. As students learn more and more concepts and have more and more experiences the principles become meaningful and useful to them in explaining and predicting their environment.

"In the first nine grades the cumulative program should be in operation and it should be divided into five main topics of science: plants and animals, the human body, the earth, the universe, and matter-energy. Students should know some facts and have some experience with each of these areas at each grade level.

"In the last three grades there should be a double track program for the science student. He should have biology, physics, and chemistry. He should also have the opportunity to elect such science subjects as astronomy, geology, meteorology, human physiology, and other science subjects. These should be for the student with particular potentialities and interests in various fields of science. For those who are not going to enter the field of science as a

vocation there should be three major courses for the modern citizen: a course in the physical sciences, a course in the life sciences, and a course in current science. Each of these should be coupled with the social aspects of science so that a person graduating from the modern secondary school knows the extent of the application of science in a persons daily life."[27]

In 1956 I extended this idea but concentrated on the elementary science program.

"The role of science in the elementary school can be defined as a series of experiences a child can get in no other way or in any other place. Science in the elementary school should be a series of cumulative experiences so that students use the knowledge they have gained in one grade to make the work of the next grade more meaningful and to make it possible to extend their previous knowledge at each grade level.

"One of the roles of science in the elementary school is to help children learn concepts by a variety of experiences so that they realize the world of knowledge is the result of many, many different kinds of learning activities.

"Another role of science in the elementary school is to make possible through experience the development of a concept that has so much meaning associated with it that a child can use it in many different kinds of experiences.

"The primary grades are good grades to emphasize through experience that the role of science in the elementary school is one of helping the child describe the environment in which he lives. In the intermediate grades the role of science is the beginning of true experimentation. Throughout the elementary school a continuing role of science is helping children learn scientific attitudes."[28]

Each science teacher must contribute a
visualization of science education K-12.

In 1958 I was speaking about the rationale for a K-12 program in science.

"The K-12 Program: A Definition:

No curriculum is worthwhile unless the science teacher visualizes its entirety. In 1958 this conceptualization appeared.

"K-12 means kindergarten through the 12th grade. Program means the experiences young people have in school through which they develop those concepts associated with the fields of science. The nature of

these concepts is twofold: concepts associated with the products of science (science content) and concepts associated with the scientific modes of thought (the processes by which scientists develop new science concepts).

"The K-12 Program: Its Objective:

"The objective of the K-12 program is an organized, sequential series of experiences beginning in the kindergarten and continuing through the 12th grade which hav a cumulative effect in that each experience helps the student develop science concepts that help him to continually better understand major scientific principles and processes.

"The K-12 Program: The Reasons for Studying It:

"We have concerned ourselves with the whole child but not with the whole program of the whole child. Educators have urged us to conceive all aspects of education as effectors of the total personality structure of the student. It is their contention that any experience is responded to and effects an individual as a functioning whole organism rather than one whose parts function separately during various experiences. We have accepted the principle that ontogeny recapitulates phylogeny in the growth and the development of each individual of a species but we have had difficulty in accepting this same viewpoint in reference to education. The sum total of student's experiences as an individual in a culture directs his behavior in each new experience and each experience refashions that behavior in reference to the sum total of his experiences and the personality structure that has developed as a consequence of them.

"If this premise is accepted then growth and development and their concomitant changes in behavior make it essential that we carefully consider the series of experiences in science the student will have for his 13 years of public school education, if we have values in mind which we would like to see become a part of the individual. The acceptance of this premise means that we must survey, examine, evaluate, and appraise carefully the total program in science as well as the total individual who will participate in it."[29]

In 1959 I refined these thoughts in listing the characteristics of a good K-12 science curriculum.

"1. A planned science curriculum beginning in the kindergarten and continuing through the 12th grade.
"2. A curriculum characterized by the careful selection of experiences for each grade level that enable students to develop science concepts.

"3. A planned sequence of experiences that result in a continually growing and developing understanding of basic science principles.
"4. A program that gives experiences in all areas of science to both boys and girls at each grade level.
"5. A curriculum designed to add new experiences and new concepts to the education of the children at each grade level.
"6. A program that includes experiences to promote continual growth in the mastery of skills essential to problem solving and the development of scientific attitudes.
"7. A program that recognizes that children will develop concepts of varying qualities from any one experience and evaluates to discover the quality of the concept the child has developed."[30]

In 1960 I attempted to use the concept of the evolution of a natural community to its climax state (learned from Samuel Ralph Powers, Teachers College, Columbia University, 1941) to set the stage for a summary statement concerning the K-12 program concept.

"We often have our feathers ruffled by the winds of conflict set in motion by those who think differently than we do. Sometimes we are chilled and sometimes we are overheated by the extremes in temperature produced by various pressure groups. The light of inspiration that emanates from the men of distinction speak of and about education stimulates us. We are often caught in the riptide of the fluid, liquid interests of our students that seep into every crevice and cranny of the universe. We are gorged with the fine fruits of scientific experiment.

"Our stimulus-response mechanisms are barely equal to adapting to these forces of interaction present in the environment of science education today. Whether or not these forces can be molded and welded together to produce a climax community of cooperative, intelligent, and stable thought in science education will be determined by those who compose the present community. The one causitive factor in these ecological relationships that may enhance and brighten the future of our community may well be the collective desires for improvement by those of us who have dedicated our professional lives to the problems of science education. The emergence of the climax community may well depend upon our abilities to appraise realistically the state of affairs of this community.

"We need to develop a scientific mode of thinking for science educators that makes us refrain from using personal opinion as the final judgment in periods of decision making. We should reject the past as the sole determiner of the future. The good of the past is

good now, only if it is good for something at the present moment. We need to accept the idea that if we agree something is good to do ten years from now, now is the time to do it.

"Within any community individuals must, of necessity, recognize the bright comets of educational thought for what they are. We have seen many of them suddenly appear and disappear. Some of our members have become missionaries and have burned themselves out in the white, hot heat of fiery vision. Some have panicked during sudden innovation and changed jobs.

"Within any developing community we must, from time to time, live with the hot fires of criticism that belch forth spontaneously from the magnificent volcanoes of human emotion possessed by some individuals. The hot lava spews from their minds and tongues and spreads across the land, searing and burning and destroying some people, irritating and stimulating others to action to bring the volcanoes under control. Uncountable numbers of people have attempted to perpetuate an ice age through their glacial action on the science programs in an attempt to freeze them into insignificance or bury them under the accumulated tons of dogma built on the mountain tops that of its own weight spreads to the valleys below, directing the lives of many rather than being directed by them. All of these forces help characterize the ecology of our educational community.

"The present events on the continent of education--the slow erosion of those great Appalachian programs conceived prior to the scientific revolution and the slow rise of the Rocky Mountain curricula now in the making--must not be the victims of the runoff waters of indecision of either mountain chain for they might end in a vast river of educational sediment eventually deposited in the great ocean of education experience, to metamorphize into layers of programs whose fossil remains are so fondly studied by the students of the future who are interested in the quaint approach to crisis we were so satisfied with in the twentieth century.

"What is this K-12 program to which we have devoted so much of our effort and time this year? To me its establishment will be the climax community of science education."[31]

SUMMARY

Promote revised changes in science education as science and society change.

Patricia Blosser, in her letter of invitation to write a chapter for the yearbook, suggested that the contributors might devote some thought to the future of science education as we saw it. I believe I did that in a speech in 1958.

"Ever since Russia shot a small sphere into the air that rose to its predetermined orbit and beeped continually around the earth, we have had strange and peculiar reactions to our own way of doing things in science education.

"For the education needed 30 years in the future, 1988, let us now educate our present generation to live in space ships, to cope with the problems of landing and living on Mars, with the problems of a united galaxies, for a peaceful universe, with the problems of automation where machines replace men, with the problems of no automobiles and transportation entirely by air, and perhaps through wires, with an age in which communication orally is unnecessary and mental telepathy is possible with the goal to think well rather than talk well.

"Let's educate students to be ready to cope with additional leisure hours and days each week as machines do more and more of the work and man does less and less of the work. Ah, yes, for the final coup d'etat, the role of piloting and traveling in flying saucers.

"The nation would rise in arms at such suggestions--preparing the children for the future--but when that future comes they will rise in arms because they were not prepared.

"If the public wants the best science programs that we know how to produce, give us the money and the teachers. If you want a good science program give us the money for the laboratories and the equipment. If you want well trained teachers, give us the money to do it. Give us adequate classrooms and adequate laboratories, set aside $50,000 to put science equipment in the public schools of each community. And I don't mean the old science equipment that was used in 1900. I mean the equipment youngsters should learn with now: telescopes, atomic piles, models, radioactivity models, seismographs, gravity determiners, the materials of the International Geophysical Year (IGY). Yes, it will cost, but how else will you educate them to be ready to use them? Give us money to send our teachers to Oak Ridge and Brookhaven. The world moves

on and knowledge changes. Give us models of rockets and satellites and the instruments in them. Make it a science curriculum of this century."[32]

And again in 1962, "The problem of curriculum construction in science is not one of making a curriculum, it is the problem of modifying the present curriculum for more effective K-12 education of youth.

"The important problem in education is not who should teach what but when and how it is most effective for boys and girls to learn. Leadership should be a directive for the future and not an analysis of the present.

"The conception of what is science, like the conception of what is marriage, is in direct relationship to the maturity level of the student. It is different things at different times in the maturation process.

"Experiences and concept development at various grade levels should be determined by the prevalence of these experiences and concepts in the culture that are selected in reference to the science maturity of the student."[33]

The content of this chapter may leave the reader with a sense of futility, a feeling that there is very little to be gained by devoting a life to the improvement of science education. Possibly the ideas were not appealing to others but one wouldn't want to think about that, would one?

I have tried very hard to be honest, to objectively evaluate the results of my efforts but not to discourage, only to reveal the experiences of a change agent in any segment of education. That is why I ended the chapter with the section THE TRUMPETS SOUND. After a lifetime of struggle an idea "caught on." NSF has accepted it and is proposing a study of the status of the K-12 programs in the United States.

Anyone who has suggested change understands the emotional reaction that accompanies the ideas. Those who accept the challenge of avidly seeking improvement should be ready to accept defeat and to be humble with success.

If the individual drive to bring about change in any facet of our society disappears, society is doomed. The strength of one's beliefs is satisfying and respect is the reward.

What is the directive for the future? Who knows? Those now in a position of leadership will probably determine it. May they with an understanding of the substance of the past offer well thought out recommendations for the future.

SPEECHES

1. "An Analysis of the Proposed Objectives for Science Teachers," Colorado State College, Faculty Meeting, Greeley, Colorado, 1944.

2. "The Secret City," 1949.

3. "The Ecology of the Educational Community," American Association for the Advancement of Science, Chicago, Illinois, 1960.

4. "A Life Is a Lesson," National Science Teachers Regional Conference on the K-12 Program, New York, New York, 1959.

5. "The Or ntation of Teachers," 1942.

6. "Sex Education," 1949.

7. "Atomic Energy " North Carolina Speaking Tour of Ten Cities, 1950.

8. "The Teaching of Science in the Junior High School," 1950.

9. "My Community," North Carolina Speaking Tour of Ten Cities, 1950.

10. "A Neglected Subject," North Carolina Speaking Tour of Ten Cities, 1950.

11. "Conservation," 1953.

12. "Physical Science and Space Science," 1965.

13. "Elementary Science--Purpose and Future," Workshop, University of Houston, Houston, Texas, 1960.

14. "The Role of the Teacher," 1939.

15. "A Common Knowledge," North Carolina Speaking Tour of Ten Cities, 1950.

16. "A Common Knowledge," North Carolina Speaking Tour of Ten Cities, 1950.

17. "The Role of Science in the American Public School System," Annual Conference of Department of Elementary School Principals, University of Denver, Denver, Colorado, 1958.

18. "The Education Satellite," Men's and Women's Graduate Clubs, Colorado State College, Greeley, Colorado, 1963.

19. "A Common Knowledge," North Carolina Speaking Tour of Ten Cities, 1950.

20. "Junior High School Science," 1962.

21. "Science Education, " Phi Delta Kappa, 1949.

22. "The Life Adjustment Program and the Present Curriculum" Colorado Education Association Convention, Pueblo, Co [illegible], 1949.

23. "Mollusks and M rals," Arizona State College, Science Workshop, Flagstaff, Arizona, 1948.

24. "The Ecology of the Educational Community," American Association for the Advancement of Science, Chicago, Illinois, 1960.

25. "Implications of the Conceptual Scheme for the Curriculum," Washington Junior High School Principals' Association, Spokane, Washington, 1962.

26. "Junior High School Science," 1962.

27. "Our Common Task," Colorado-Wyoming Academy of Science, Colorado State College of Education, Greeley, Colorado, 1955.

28. "The Role of Science in the Elementary School," Annual Conference of Department of Elementary School Principals, University of Denver, Denver, Colorado, 1956.

29. "The Role of Science in the American Public School System," Annual Conference of the Department of Elementary School Principals, University of Denver, Denver, Colorado, 1958.

30. "Growing Up With Science," National Science Teachers Association, St. Louis, Missouri, 1959.

31. "The Ecology of the Education Community," American Association for the Advancement of Science, Chicago, Illinois, 1960.

32. Title unknown, 1958.

33. "Positive Principles of Science Education, 1962.

REFERENCES

1. Blosser, Patricia E. "A Study of the Science Interests of Junior High School Students at Wooster High School, Wooster, Ohio." Master's thesis, Colorado State College, 1966.

2. Commission on the Reorganization of Secondary Education. *Cardinal Principals of Education.* U. S. Bureau of Education, Bulletin No. 35. Washington: Government Printing Office, 1918.

3. Committee on Curriculum Planning and Development. "The Place of Science and Mathematics in the Comprehensive Secondary School Program." *National Association of Secondary School Principals* 42(September 1958):5-12.

4. Comstock, Anna Botsford. *Handbook of Nature Study.* 24th ed. Ithaca, N.Y.: Comstock Publishing Company, 1939.

5. *Cornell Rural School Leaflets.* 62 vols. Ithaca, N.Y.: The New York State College of Agriculture at Cornell University, 1907-1969.

6. National Society for the Study of Education. *A Program for Teaching Science.* Thirty-first Yearbook, Part I. Chicago: University of Chicago Press, 1932.

7. Patch, Edith M., and Howe, Harrison E. The following are books in the *Nature and Science Readers. Hunting; Outdoor Visits; Surprises; Through Four Seasons; Science at Home;* and *Work of Scientists.* New York: Macmillan, 1932-1935.

8. Persing, Ellis C., and Peoples, Elizabeth K. *Elementary Science by Grades.* Books 1, 2, and 3, ed. Frank W. Ballou. New York: D. Appleton-Century, 1928-1933.

9. Shapley, Harlow. *Of Stars and Men: Human Response to an Expanding Universe.* Beacon Hill, Boston: Beacon Hill, 1958.

10. Snow, C. P. "The Conflict of Cultures." *The Saturday Evening Post,* September 12, 1959.

11. U. S. Office of Education. *Life Adjustment Education for Every Youth.* Bulletin No. 22. Washington: Federal Security Agency, 1951.

H. Seymour Fowler was born in 1919 in Michigan. His elementary and secondary education was obtained in the states of Michigan and New York. After graduation from high school he attended Cornell University from which all of his higher education degrees were awarded. His B.S. was awarded in 1941 and after four years of military service he returned to Cornell where his M.S. was awarded in 1946 and his Ph.D. in 1951.

Dr. Fowler taught secondary school science in New York state from 1946 until 1949, he served as an instructor in science education at Cornell from 1949 until 1951. In 1952 Dr. Fowler moved to Iowa State Teachers College (now the University of Northern Iowa) as assistant professor of biology and Director of the Iowa Teachers Conservation Camp. In 1957 he joined the Pennsylvania State University faculty as an associate Professor of nature and science education and director of the Pennsylvania Conservation Laboratory for Teachers. Dr. Fowler became professor in 1965 and has served as chairman of the Science Education Faculty since 1969.

Dr. Fowler has been an active member in NSTA, AAAS, AETS, AIBS, NABT, NARST, American Nature Study Society, and the Pennsylvania Science Teachers Association. He served as president of the American Nature Study Society in 1967 and president of the Pennsylvania Science Teachers Association in 1976. He was also vice-president of NABT. He was elected a fellow of AAAS and has served in a number of leadership roles in NABT.

Dr. Fowler has served as director of the Junior Science & Humanities Symposium and of the Pennsylvania Junior Academy of Science. During his career he also advised and consulted for science-related educational television programs. He also served as a consultant to the Korean Biological Education Study Commission in the translation and implementation of the BSCS Green Version. Dr. Fowler also served as director of several NSF Experimental Programs in Elementary Science Education.

Dr. Fowler has published and researched extensively. His articles have appeared in numerous education and science education journals.

Dr. Fowler was awarded a Fulbright Lecturer Grant in Science Education to the Republic of Korea in 1968-1969. He was presented with a Pennsylvania Department of Education Certificate of Commendation for his contributions in conservation in 1970. The Pennsylvania Science Teachers Association presented him with a Meritorious Service Award in 1975 and the NSTA recognized his professional service with a Distinguished Service Award in 1976. He received the Honorary Member Award from the National Association of Biology Teachers.

SOME COMMENTS ON THE HISTORY OF SCIENCE EDUCATION IN THE UNITED STATES

H. SEYMOUR FOWLER

Chairman, Science Education Faculty
The Pennsylvania State University
University Park, Pennsylvania

The science educator or practitioner recognizes that any system is the product of its history. Also, the science educator will recognize that we can understand elements of the system as seen in the present by studying the past and perhaps by so doing our past errors need not be repeated.

It becomes evident to the careful observer that the direction taken by education is influenced both by time and place. In no location has this been more evident than in the United States. If we look at objectives, methodology, and content of secondary school science education in the United States it becomes obvious that all three have been profoundly affected by the history of our developing nation. In fact all three, the objectives, the methodology, and the content of science education, have evolved in consort with the developing nation. Science education is no exception to the contention that it reflects the influences of time and place.

EVOLUTION OF SECONDARY SCHOOLS

The evolution of secondary schools from the Latin grammar school to the American academy to the high school illustrates the development of and gradual but inevitable change in school systems in the United States. Time and place and schools evolve together.

Even though the settlers in the new world (the American colonies) intended to start anew in their religion, politics, and methods of earning a living, history tells us that the immigrants planned no new starts in their provision for secondary education. They simply transplanted the old world European humanistic secondary school to a new locale. These humanistic secondary schools were not really "new." They had been tried out in Europe and had established a pattern of the study of Latin and Greek tongues by youth who were supposed to then understand antiquity. The schools developed with an objective of studying man in all of his humanity, whatever that

means. By so doing, students were supposed to learn and speak Latin elegantly. In the old world these so-called Latin grammar schools evolved into the secondary schools--colleges and lycées of France, the gymnasium of Germany, and by the same name the Latin grammar schools of England.

The Latin Grammar School

The early settlers in the colonies tried to imitate, if not duplicate, their homeland's schools. Therefore, it seems appropriate to discuss the transition here. The English Latin grammar school provided the pattern for most colonial secondary schools. One must remember that the early settlers to the new world came to our Atlantic seaboard and many had their origins in those groups searching for religious freedom. As a consequence the new world's secondary schools tended to follow a reformation pattern of humanistic education of origin north of the Alps rather than one of the Renaissance pattern to the south. Therefore, if a young boy were enrolled in a Latin grammar school he did not expect to cultivate an aesthetic enjoyment of those elements designated as the humanities. On the contrary he expected, even more, to prepare himself to enter the colonial colleges and enter a profession related to the church or state. In his curriculum the student expected humanistic rather than naturalistic studies, classical rather than scientific studies. The proponents of the Latin grammar school described their studies as formal discipline of the mind.

We must remember that boys entered the Latin school as early as their seventh or eighth birth date. Generally by that time th had learned to re . Nevertheless, some Latin grammar schools included reading as one of their subjects. Probably preparation in the Latin grammar schools in the new world did not advance one's education to as great a degree as it did to promote social mobility both in one's economic class and in one's social status. As such the Latin grammar school remained the typical colonial secondary school during the seventeenth and eighteenth centuries. However, it is safe to say that the school never became an important force in the development of the life of the Atlantic seaboard.

So let us pause here and consider that we have described an apparent expression of education reflecting time and place. Here were the colonies closely attuned to the motherland and their schools reflected this relationship. However, this would appear to be only a superficial emphasis because apparently there were within the colonies seeds of change. Latin grammar schools flourished and expanded but they remained localized at their best. Massachusetts passed statutes requiring towns of a certain size to establish and maintain a Latin grammar school. Massachusetts was apparently the leader in secondary school education in those early days. It is

of interest to note that the Latin grammar school in its new setting in the colonies served the needs of a small percentage of the population, in particular in our southern regions. As a result, long-time, adequate support for Latin grammar schools was impossible. The "intellectually elite" were too few and not concentrated in places where Latin grammar schools might develop.

It may be useful to "look back in time" and examine the function of a beginning attempt at secondary school education in those early colonies which later became the nucleus of the United States. It would seem apparent that the Latin grammar schools served their purpose. The young developing nation had not yet severed its ties to the parent establishment, England. Programs of education in the Latin grammar schools in the new world did imitate and reflect their precursors or progenitors from the old world. This they did and as such they served their purpose of providing personnel to assume leadership roles as members of the clergy or civil servants for the state. Today in the United States there is no semblance of this earlier school system which was an import and transport from the old world. We find no science courses in the offerings of the Latin grammar schools. This is understandable because science had not yet become established nor were the objectives of the Latin grammar schools in accord with a direction of objectivity in content coverage. Nevertheless, the existence of the Latin grammar schools in the seventeenth and eighteenth centuries reflects the pressures of time and place.

The American Academy

We move historically now into the eighteenth century and the establishment of a new form of secondary school in the colonies, the American academy. The older form of administrative organization--the Latin grammar school--apparently could not cope with changing social conditions. We must remember also that secular interests began to crowd religion out of its dominant position in people's minds. Political ferment was also in evidence in the eighteenth century. The colonies had begun to develop unsatisfactory relationships with both England and France. The colonists became a unified ~~group of~~ states with interests in the scientific movement. As a result it became increasingly apparent that the colonies would need a new and different educational system that would do more than prepare young men for the ministry or for a place in government.

We find the new schools, the academies, developing both in England and in the colonies. It is not known exactly whether this development reflected similar stimuli. It is apparent, however, that in both situations the schools represented a distinct change from those which preceded them, the Latin grammar schools. Of interest is the fact that Benjamin Franklin (1706-1790) statesman,

scientist, and man of many talents proposed the establishment of the first academy in Philadelphia. Unfortunately Franklin's academy did not apparently catch the fancy of hi fellow Pennsylvanians and became in time a college-lev l institution. Massachusetts proved a more hospitable location for the academies and one of the early successful academies was one at Andover established during the Revolution. This academy at Andover proposed to train boys for life. The academies also expressed a concern for education for the terminal student and so we find an attempt to do just that--in addition to preparing young boys for college.

Perhaps here we find the early beginnings of what became the comprehensive high school movement. Different subjects were presented which included not only the old Greek and Latin grammar but also practical geometry, logic, and geography. This was a departure from tradition. However, Franklin's academy proposed even greater changes including dispensing with the classics. In addition the inclusion of arithmetic, geometry, and astronomy were suggested as subjects which illustrated Franklin's and the academy's emphasis on utilitarian education since some of the major occupations of the day were seamen, surveyor, and merchant. Also emphasized were the natural sciences, geography, history, and morality. It was important, according to Franklin, to view history in terms of its social uses. Franklin perhaps was ahead of his time. At least his contemporaries in Philadelphia dissuaded him in his major revisions and so the Philadelphia academy maintained the classics.

Academies grew in numbers and in the number of courses presented Apparently they fulfilled a real need. For those of us interested in the sciences it is of importance to note that chemistry and natural philosophy were included in the curriculum of some academies. Some scholars would object to the statement of an association between the time and the place and the establishment of the curriculum of the academy. However, it must be remembered that the nation was young and there apparently was a strong belief in establishment of experimental curricula if the studies would offer a young man a portunity to develop in th new experiment in self-governmen

Academies grew slowly in numbers at first but in the period from 1825-1850 they reached the height of their popularity. Many things helped to foster the growth of the academies including their acceptance by New York State and the inclusion of girls in the academies. Again, by conjecture, perhaps all of these developments reflect the young nation's attempt to live up to its Bill of Rights and Constitution. However, probably the best assessment is that the academy was a transition stage between the old world Latin grammar school and the yet to come American high school.

The American High School

The American high school did not supplant or replace the academy as an initial development. The American high school as a system appeared early in the historical development of the academy--in fact, at the time when the academy was showing its period of greatest growth. This, again, points to the transitional nature of the academy. The proponents of the high school did not want to develop an institution which would replace the academy. On the contrary, they would appear to have attempted to improve and at the same time imitate the programs of the academies. The high school's originators hoped to prepare a program for young men who would not go on to college and who would enter all phases of commercial life. Important provisions were envisioned: 1. education at public expense and 2. a continuation of common school education.

The first high school was the English Classical School in Boston; the year, 1821. The "classical" was soon removed from the title and a new name, English High School, was accepted. Only a short time elapsed before "high school" as a title was accepted. Boston's experiment was a success and Massachusetts provided enabling legislation within the decade to develop additional high schools. The high school movement followed or accompanied democracy loving people to the West and became their pattern of post-elementary education. It can be stated that the high school provided what Americans thought they stood for--education for all children at public expense with a curriculum attuned to the needs and interests of the masses. Here again we note education as a function of time and place. As in subsequent educational developments the use of public support was questioned. The famous Kalamazoo Case in Kalamazoo, Michigan, tested the legality of assessing taxes for the support of education beyond the common school (elementary level). In that very famous decision the courts ruled that a liberal education should be provided to youth of the state in schools which were within the reach of all of the classes.

After 1874 the high school movement grew by leaps and bounds. In only 20 years (1870-1890) the number of high schools increased by five times in number. In 1890 slightly more than 2,500 high schools existed with around a quarter of a million students. If we consider similar data from 1900-1940 high school enrollment increased by 1200 percent.

This fantastic growth in high school population and numbers of facilities reflects America's growth in population, but not this alone. There was a steady increase in the standard of living of Americans. There were great numbers of children of immigrants who had to be brought into the pattern of the developing democracy. On the frontier attendance at the public school and completion of its requirements were used as a means to social mobility. This

was not, however, the complete story. In later years, particularly after the Great Depression of 1929, there was little else youth could do except to remain in school. Some interesting, and sometimes rather short, science courses appeared in the early high schools: astronomy, geology, natural philosophy, agriculture, chemistry, natural history.

We see early beginnings of later high school science offerings if the content of natural philosophy and natural history is examined. Natural philosophy contained materials from astronomy, the earth sciences, and physics. Natural history on the other hand included about equal portions of botany and zoology with no attempt at integration. Emphasis in natural history was on learning facts and on the physiology and morphology of plants and animals.

College Domination

There is another interesting period in the history of science education in the U. S. which is superimposed in time over that of the high school movement. For convenience this may be referred to as the period of college domination which was at its height in the last quarter of the nineteenth century. A similar effect was felt in American high school science education in the post Sputnik, 1957, era--an era of hysteria, almost, in which the public called on the professional scientist to assist. To return to the first period, the last part of the nineteenth century, Harvard University led the way and by so doing helped to standardize high school science courses. In 1872 Harvard began accepting science courses from a student's high school background as entrance credits. By so doing, Harvard could dictate what were acceptable not only as high school science courses but also what the content might be in the courses. One standardizing document of interest was the Harvard Descriptive List (1887) which reported the 46 acceptable experiments in high school physics which could be used for college entrance.

During this period from 1870 to 1900 high school science courses became miniature college science courses. College professors prepared the courses of study used in high school sciences and they wrote the textbooks. The science courses had little or no practical value but instead served to prepare the student for more of the same in college. This same influence of college personnel on high school science courses was again in evidence in 1970 and had been so for some fifteen years prior to 1970.

To return to the earlier period of college domination: One must remember that the high schools post-Civil War and into the early years of the twentieth century varied greatly in program and quality. This same criticism could be leveled at the colleges. Therefore, an attempt at standardization was in order. In addition

to Harvard, the University of Michigan developed a system to encourage a similarity of high school preparation. Michigan appointed a visiting committee of staff members who, upon invitation from a high school, would visit that school and study the quality of the work done there. If the committee was pleased with what it saw, students from that particular high school would be admitted to the University of Michigan upon receipt of a letter of recommendation from the high school's principal.

Accrediting agencies were formed in various regions--the New England Association of Colleges and Preparatory Schools and the North Central Association being examples. All of these attempts at standardization of offerings and of quality, with their dictation from above, were simply forerunners of the College Entrance Examination Board, the most widely accepted college entrance examining body in the nation.

One must include in this segment of the history of science education in the U. S. mention of the Committee of Ten on Secondary School Studies of the National Education Association (NEA), which through its reports in the last decade of the nineteenth century developed into one of the most formidable of the standardizing agents (28). The earliest objectives of the Committee of Ten were quite democratic. It hoped to standardize high school offerings so that all secondary school graduates who had completed their school work successfully would be able to enter colleges of their choice. This was the wrong time for such idealism. It soon became apparent that subjects taught in different secondary schools could not be taught in the same way and to the same extent to every pupil.

Another standardizing agent was the Committee on College Entrance Requirements, again an appointee of NEA [illegible] This committee made many recommendations, two of which are of special importance here. First, the committee recognized the elective principle as worthy of at least partial recognition in the high school curriculum. So it proposed that elective subjects in high school should be recognized. This helped to decrease the commanding influence of upper echelon agencies such as the colleges and especially appointed examining boards. There was also in the committee's recommendations a beginning of the concept of equivalence of studies. The committee recommended that any course within the high school should be considered worthy to count as a credit toward admission to college. Here we see the beginning of a system of units or credits for high school science courses and another yardstick for standardization.

For example, prior to the reports high schools offered a variety of *short term* science courses including astronomy, botany, chemistry, geology, physics, physiology, and zoology. This practice was replaced with *full year* courses and the wide range coverage was

greatly reduced. So we observe from an examination of these early post-1900 high schools the following common four-year sequence: year 1, physical geography; year 2, biology; year 3, physics; year 4, chemistry. As a result of the sequence, other developments followed: the encouragement of quantitative laboratory work, the development of laboratory-type teaching, the encouragement of the use of materials readily obtainable resulting in a lower budget for equipment, the realization that collegiate training for teachers was an essential prerequisite to successful high school science teaching. The use of field trips was encouraged as was the development and maintenance of a good high school library. Double laboratory periods were supported and it was recommended that descriptions of experiments completed in the laboratory be recorded in notebooks.

In spite of these advances, all was not gain. In response to the "call for notebook records" there developed a near stereotyped method of reporting including almost always:

1. The title of the "experiment."
2. Purpose of the "experiment."
3. Procedures.
4. Results.
5. Conclusions.

There was a strong tendency to develop one mode of instruction in an attempt to meet the specifications of the examinations and the syllabi. Textbooks were prepared from syllabi or curriculum guides and curriculum guides were prepared as a result of the study of existing textbooks. In addition there was an inordinate emphasis on the assimilation of subject matter of science as the end result of instruction with little emphasis on how that subject matter of science had been acquired. In later decades (1950s and 1960s) we heard this same criticism of high school science teaching as the hue and cry of the critics of American high school science education: our high school science teaching emphasizes the knowledge of the products of science at the expense of the understanding of the processes of science.

SCIENCE REQUIREMENTS FOR ELEMENTARY GRADES

To this point we have not described science requirements for elementary grades. It would seem appropriate to do so now since the recommendation of the two NEA committees (Committee of Ten and the Committee on College Entrance Requirements) also suggested standards in this level of public school education. Nature study was suggested as the science component of the elementary grades. In contrast to the committees' recommendation that four periods be utilized for the high school sciences only two periods were recommended for nature study.

The nature study movement had an important influence on science teaching in our public schools and so some of its salient features are reviewed here. Again we recognize a reflection of occurrence of change resulting from time and place. The time is the early 1900s (1900-1930). There had been and was continuing a great migration of persons from foreign lands to the U.S.A. Agriculture was in its prime but at the same time there was a beginning trend toward urbanization. People were moving to the cities and were attracted there by the industrial development in the nation spurred at least in part by World War I. In the country there was still support for aesthetic values and moral commitments. Nature study fostered these two goals but at the same time was a response to the trend toward urbanization also. The movement gained its theoretical base from leadership in colleges of agriculture--in particular Cornell University--and was an attempt to check the population flow to the cities.

There was an emphasis on gardening and on "a feeling" (in the affective domain we would relate in the 1970s) for plants and animals. Those who supported nature study saw it not as a science per se but as an attitude of mind. Interestingly enough, however, the same nature study movement professed to support the following:

1. That children should study things in their natural setting in a scientific way.
2. That the things studied should be related to the children themselves.
3. That the children should not only learn to observe but should learn to interpret what they observe.
4. That the content imparted to the children should coincide with the seasonal changes (be seasonally arranged) in effect at any particular time.
5. That nature study be the basis for the study of reading, writing, and other forms of expression.
6. That nature study should be a continuous program from the earliest grades through the college.

There is a prophetic quote attributed to one of the early nature study proponents Liberty Hyde Bailey. This quote has profound relevance in an era which must remain with us many years past its initiation in the 1970s--the era of ecology, if you will. Bailey is purported to have said,

> Nature study, as a process, is seeing the things one looks at, and drawing the proper conclusions from what one sees. Its purpose is to educate the child in terms of his environment, to the end that his life may be richer and fuller.... It trains the eye and the mind to see and to comprehend the common things of life; and the result is not directly the acquiring of science but the establishment of a living sympathy with everything that is (2).

With some changes in expression and grammar, one might easily interpret the foregoing statement as an expression in broad terms of the objectives, in part at least, of today's high school science subjects. The nature study movement did contribute to science education in the U. S. but did not survive in name at least in our public school systems. It was replaced in the 1930s by elementary school science.

IMPACT OF JUNIOR HIGH SCHOOL

We should here examine the impact of the American junior high school, an educational establishment unique to the U.S.A. The development of the junior high school was abetted by the reports of the Committee of Ten and the Committee on College Entrance Requirements. A movement developed to divide the high school into two units, a junior and senior division. It must be conceded that this movement originated in part at least as a result to prepare students for college entrance. So we find strong support for "moving down" preparation in algebra, science, and foreign languages to a lower level--the new junior high school. In fact, reports urged that the 7th and 8th grades be made a part of the administrative unit of the high school--9, 10, 11, 12. A strong plea for the junior high school was made earlier by the then president of Harvard, Charles W. Eliot, to the National Education Association in 1888. Eliot argued that Americans were entering college at an age much later than their European counterparts. He therefore concluded that American secondary school education should begin two years earlier than had been customary. The response on the part of secondary schools was to departmentalize the upper two grades of their elementary schools. As a result, teachers became departmentalized also and we see here the beginning of teachers of subjects such as English, mathematics, or science across high school grade levels.

In 1912 the Committee on Economy of Time in Education of the National Education Association supported the formation of a six-year high school. It suggested that the school be divided into a three-year junior division and a three-year senior division; thus, the beginnings of the junior high school and the senior high school. By 1920 educators found and reported psychological reasons for a three-year (junior high school) intermediate school. It was argued that students of the ages of junior high school were undergoing profound physical and psychological changes. Therefore, they required--yes demanded--a different style of presentation of subject matter. Also, if a junior high school unit were available it might discourage students from leaving school, as they were prone to do at the end of the 8th grade. Probably of greatest impact on the development and establishment of the junior high

was the phenomenal increase in number of youngsters of that age level. New buildings had to be constructed and so why not make them junior high schools. All of these developments led to the establishment of a "science" for junior high schools. It was assumed that one science, general science, was the answer and proponents of this subject reported that it contributed most profoundly to the cardinal principles of education. A science sequence was given impetus. Also there arose, interestingly enough, a new emphasis on the practicality of science.

DEVELOPMENT OF SECONDARY SCIENCE EDUCATION

To summarize events in the period 1880-1920, this period saw a continuation of an emphasis on practical utilitarian science in the secondary schools. Science courses were in the early years of the period offered as short, separate courses with offerings in chemistry and physics dominating. A new emphasis on demonstrations and laboratory methods developed. Field work and the utilization of a variety of reference books became popular. In biology there was an emphasis on collecting, identifying, and describing plants. Developments in science education were probably related to the emergence of strong emphasis at the national level on agriculture, industry, and commerce. The high school began to show a marked increase in numbers and size of student population Faculty psychology dominated the scene. A movement supporting learning for learning's sake and for the discipline of the mind was in evidence. In relation to faculty psychology, science was considered particularly useful to discipline the mind. Science could be used, it was argued, to train students in developing systematic habits of work, a power of reasoning, and both precision and neatness. The laboratory enjoyed a popular support and perhaps even an introduction as a part of many new secondary school science programs. To further the course of "discipline of the mind" it was argued that in science one accomplished this because of science's formal and systematized subject matter as well as a result of involvement in laboratory work. Later science education research efforts have been unable to substantiate these claims. National committees emphasized a trend of preparing students for college and college science courses and proposed a sequence of "standardized" courses for the four-year science program--physical geography, biology, physics, and chemistry.

Some writers feel that the developments in science education in the first two decades of the twentieth century should not be included as a part of the period of college domination. It is proposed here that they may be a result of or response to the earlier developments. So let us designate the period 1900-1920 as a period of expansion and adjustment. To preview and encapsulate

developments in science education we mention influential developments in this period of two decades: General science was introduced and gradually replaced physical geography as the first year, or 9th grade, course. General science was designed to serve a dual purpose both as a terminal subject for noncollege students and as an exploratory course for those students who would later elect more specialized subjects, e.g. biology, chemistry, physics. It is interesting to note that general science courses attempted both to represent a fusion of segmented courses and at the same time proposed to preserve the practical features of existing science offerings. There apparently was a very close correlation between the burgeoning high school populations and the introduction of general science which purported to serve this group. The NEA's *Cardinal Principles of Secondary Education* (1918), further supported the functional approaches to education at the high school level (27).

Committees labored to restate goals of education in a democracy. The report of the cardinal principles helped stimulate developments of a "general science" since science was supposed to reinforce the tenets of the cardinal principles. In this period we see a strong emphasis on facts and principles in the science curriculum.

From 1920-1940 there was a shift in the emphasis in the aims of science education in such of the units which were precollege. A new and different objective surfaces, that of "social utility." One of the prime influences in this movement was Gerald Craig's study in elementary school science (9). It was suggested that the impact of science on daily life was the prime purpose of science instruction. No one could deny that science and its handmaiden, technology, were affecting the daily lives of each and every American. Therefore, it was argued that science instruction in the schools should mirror this impact of science and technology.

Influential Science Publications

We now reach the decade of the 30s and the publication of a book which had a profound effect on science education in the U. S., the Thirty-First Yearbook of the National Society for the Study of Education (NSSE), *A Program for Teaching Science* (29). This yearbook supported the so-called elementary school science approach and took a strong stand against nature study stating that it was too anthropomorphic and was too strongly influenced by sentimentality as well as unsystematic. These latter criticisms were in accord with tenets proposed by Gerald S. Craig in his defense of a study "science and its impact on daily life." The 31st Yearbook stressed understanding of the generalizations of science as a goal rather than the accumulation of facts. Many prominent science educators of the day (1930s) contributed to the yearbook and so it

can be assumed that it should have received widespread support. It did and, in fact, the generalizations in the document stood as the dominant guidepost in science education for at least two decades, to 1950.

The recommendations of the NSSE Thirty-First Yearbook were followed by and supported by the pronouncements of the Progressive Education Association (PEA) in 1938 and its report on the functions of science in general education (32). This report, entitled *Science in General Education*, emphasized the importance of developing science programs with "social utility" as a primary goal. At this point it seems important to stress that the PEA's report also emphasized that science was important as a discipline because its techniques could be used in solving social problems. Secondary school science teaching as a reflection of the recommendations of this report became more social science oriented. We find here the early emphasis on an understanding of the "steps in the scientific method" and also of "problem solving" as objectives.

Some professional scientists later were convinced that this period of emphasis on social implications of science ushered in a period of the "dark ages" of science teaching at the secondary school level. It is a period in which the secondary school science teacher attempted to develop his programs alone and there was a trend away from college domination of high school science teaching. Secondary school science teachers wrote their own textbooks, developed their own curricula, and became increasingly divorced from their college level counterparts in college science departments.

Secondary school science textbooks of the period (1930-1950) reflected the emphasis on "the scientific method." Almost all high school science texts of the time were introduced with a chapter or section which asked and attempted to answer the questions: "What is science?" and "What is the scientific method?" To answer the latter question students were taught to memorize the steps in the so-called scientific method:

1. Definition of the problem.
2. Collection of data.
3. Formulation of a hypothesis or hypotheses. Usually, however, it was proposed that the practicing scientists deal with but one of these hypotheses at a given time.
4. Test the hypothesis.
5. Formulation of "a," "one" conclusion.
6. Application of the conclusion to new situations.

With this support of knowing the steps of the scientific method came a concerted effort (sponsored in large part by the backers of PEA) to relate secondary school science teaching to the broad

areas of living. These were described as:

1. Personal living.
2. Immediate personal-social relationships.
3. Social-civic relationships.
4. Economic relationships.
5. The disposition and ability to use reflective thinking in the solution of problems.

Interwoven with all of these developments related to science and social utility there arose two distinct trends. Science, it was proposed, should be a continuum. So we find science in grades 7, 8, and 9 developing response to this and to the junior high school movement. The junior high school was supposed to be an exploratory segment in young learners' experiences and general science developed in this manner by putting together small packages or segments from the classical science disciplines. Biology arose as a secondary school subject earlier, about 1920. By 1930-1940 it was recognized as "the" subject offered in 9th grade in a 7, 8, 9 grade school system and in 10th grade in the 9, 10, 11, 12 system.

One of the publications which helped to describe the status of science education in the U. S. during the period 1930-1950 was *Science Education in American Schools* (1947), the 46th Yearbook of NSSE (30). Several trends and recommendations were made by the various committees which produced the yearbook. A few of their more significant points are summarized here:

1. Science is an important and inescapable factor in society. Therefore all citizens should understand science. This is particularly true of the representatives of the people who act on legislation.
2. Science instruction should begin early in the student's career.
3. Science is most important as an integral part of general education.
4. Science teaching goals should include skill in problem solving and an inculcation of scientific attitudes.
5. Science at the secondary school level should impart functional information, concepts, principles, instrumental skills (psychomotor), scientific attitudes and appreciations and interests.
6. The social implications of science are of importance.
7. Science content should be selected in terms of problems of social significance, e.g. health, consumership, conservation, vocations, family relations, and citizenship.
8. The subject matter of science should relate to real problems of real students in real situations encountered in daily living and should be related to the needs of the students.

9. Science content should appeal to student interest since such appeal may influence behavior.
10. Planning science course work *with* the students instead of *for* the students should be encouraged.
11. Attempts should be made to develop science courses which reflect an integration of the various sciences rather than a logical sequence within one science.
12. Courses should be organized to provide for wide application to economic and social problems.
13. A 12-year science sequence was recommended with elementary science, grades 1-6; general science, grades 7-9; biology, grade 10; physics or chemistry, grade 11; and physics or chemistry, grade 12.
14. Inductive and deductive teaching methods of teaching are both encouraged and units of work should be planned around an integrating theme, it was urged.

So by 1950 we had in two decades survived a great depression and a horrible great world war. Science education in the U. S. in 1950 then reflected the time and the place. Consumer education was an earlier answer in the thirties and general education and training for the technician arose in response to World War II. There was an inflated demand for special training in technical fields. Such things as air age education reflected the nature of the times as did atomic age education at a later date. We begin to see a division between the scientists and their spokesmen and the educators and their spokesmen which became even more obvious in the 1950s. The scientists argued for:

1. Greater attention to the social implications of science.
2. Greater emphasis on training for those with special talent in science and the future scientist.
3. An increasing emphasis on the nature of science.

On the other hand, the educators defended:

1. An emphasis on student needs in designing science curriculum and course objectives.
2. The teaching of the methods and techniques of the scientist as useful procedures for solving problems in the daily life of the student.
3. The development of scientific attitudes as a major goal of science teaching.

During this period 1930-1950 there was an increasing emphasis on the products of science (technology) in science textbooks for secondary schools. Science teachers wrote their own curricula and wrote their own texts. There was no attempt to make little scientists out of little students. As was reported earlier some

refer to this period as the "dark ages of science education in the U. S.." Nevetheless, others refer to it as that time when the science teacher was in control of his own destiny and developed science courses to fit the needs of his students as they evolved.

The Sputnik Era

From 1950 to 1970 has been called many things by those who tried to interpret changes on the American scene. This was the "period of plenty" for the professional scientist and his effect on secondary school science curriculum was profound. The people of the United States and their spokesmen in the Congress made funds available in great amounts for the improvement of science education. Americans have been notorious over the years in their outspoken criticism of the public schools of their country in spite of the schools' fantastic contributions to our society. At no time in our history were the critics more active than during the 50s and 60s. A portion of this criticism was well-deserved. Some criticism reflected a real and honest concern. Some merely was used as means of exploiting the bias of the critic. The year 1957 brought to the world the realization that Russian science and technology was well advanced and *sputnik* became a household word. Even though many efforts had been in progress at the national level to bring about change in american science education, sputnik probably provided the foremost impetus. This period of 1950-1970 may be regarded as the "Period of the Professional Scientist as the Architect of Science Curriculum in the Secondary School."

One of the results of this revolution in secondary school science was a reorientation of almost every phase of science education. By 1970 we saw the following trends in evidence:

1. Science courses were written at even higher levels of meaning.
2. Courses were structured around conceptual schemes or themes or "big ideas."
3. A small number of big ideas formed the framework of the courses.
4. Science became a specialty of supervisors and so larger school systems employed science supervisors.
5. The logical structure of the discipline became a framework of sequencing learning activities.
6. The laboratory became an integral part of instruction with its objectives somewhat changed in emphasis to include the raising of problems, the testing of the skills of inquiry, and the provision of experiences for "discovery."
7. The subject matter of high school science was prepared by research or professional scientists. It was emphasized that the student should be introduced to the "frontiers of science."

8. There was an emphasis on problem solving, guided discovery, and discovery as methods.
9. There was an emphasis on science as process rather than science as product.
10. There was a negative reaction to the social utility approach to teaching science.

Public interest and public support of science education was widespread. The Congress passed the National Defense Education Act (NDEA) in 1958. Funds provided in this act made it possible for elementary and secondary schools to purchase additional equipment and reference books for science as well as for mathematics and foreign languages. Some skeptics believe that NDEA could never have been passed without the *D* (Defense) and that the act reflected the time and the place. That is to say historically we were in the cold war period when we were not just quite convinced of the superiority of the education system in our country. Several references were made at the time to the superiority of European, in particular Russian, education. There came into being a National Science Foundation (NSF) which was a private agency supported by public funds. Those funds were used in many ways and attempts were made to upgrade science education. Summer and year-long science institutes for science and mathematics teachers were supported by NSF. These programs designed to upgrade the science preparation of secondary school teachers were conducted by colleges and universities throughout the country.

Probably the major result of the ferment in science education from 1950-1970 was the development of a new assortment of science curricula in almost all areas and levels of elementary and secondary science.

Impetus for Change

Since 1945 and particularly after 1955 secondary school science courses have undergone many changes. Many factors gave impetus to these changes. Some of the more important and well known factors are enumerated here. Science became an enterprise of increasing importance and knowledge in the broad field of science and its many subdivisions increased at an ever accelerating pace. There was, in particular, after 1957 an increasing concern that Russia was a real threat in both scientific fields and in technology. After the launching of sputnik, critics and public criticism of American science education in the mass media became commonplace. Many were concerned with the development of nuclear energy as it was applied for destruction in war. So American science teachers were encouraged to add another element to their already crowded curricula, namely atomic age education. Also there was a great increase in the secondary school population which was a reflection of the birth rate after World

War II. Educational technology, e.g. television, became an important learning aid. We gained new insights into how people learned science. Perhaps most important were the huge sums of money provided by private foundations and the federal government which were used to change science curricula and influence science teacher education programs. The professional scientist became a secondary school science curriculum specialist.

Many secondary school science curricula developed as a result of all of these influences. They became known as the alphabet programs because their longer titles were frequently abbreviated by combining several of the beginning letters of the prominent words in their titles. As examples of the acronyms:

TSM	Time, Space, and Matter
ESCP	Earth Science Curriculum Project
IPS	Introductory Physical Science
BSCS	Biological Sciences Curriculum Study
CHEM Study	Chemical Education Materials Study
CBA	Chemical Bond Approach (Chemistry)
PSSC	Physical Science Study Committee
HPP	Harvard Project Physics, later Project Physics
ECCP	Engineering Concepts Curriculum Project

Although these are different programs, their authors followed a sequence of activities like those given below:

1. Funding was obtained from an outside agency, which very frequently was NSF.
2. University and/or college scientists were the prime movers of the projects.
3. Secondary school science teachers were enlisted as coworkers.
4. Writing conferences were scheduled and curricular materials were produced by teams of college-level scientists and high school science teachers.
5. Curriculum trials were scheduled in cooperating secondary school science classrooms. Feedback from one or repeated trials was used in making revisions of the new materials.
6. Secondary school science teacher summer and/or academic year institutes were prepared by colleges and universities to prepare high school science teachers to teach the new programs.
7. Supplementary materials including such things as apparatus, films, laboratory guides, models, and teacher's guides were prepared.

Even though in different subdisciplines of science the "new science courses" exhibit similarities in both their objectives and in the types of materials made available to secondary school science teachers. The following are examples of these similarities:

1. They claim to be prepared not for an academic elite school population but for students in comprehensive high schools.
2. It is difficult to locate examples of the application of science technology in most of the new courses.
3. As a generality we find much less attention given to the products of science and more to the processes of science.
4. All of the curricula claim to employ a discovery approach in which the student serves as the discoverer.
5. Subject matter is presented at a much higher level of rigor which some have claimed is an example of moving down content to the secondary school from its former place in college-level science curricula.
6. A different trust in emphasis on the quantitative aspects of science is common.
7. Students learn to gather data, record information, and analyze data individually or as a team.
8. Formal methods of reporting experimental data are used.
9. A majority of the curricula developers claim that more contemporary topics "on the frontiers of science" are included.
10. All present science and scientists in a manner which attempts to influence favorable attitudes toward both.

The development and use of the funded programs reflect time and place. So much of man's daily activities post-1950 were and are affected by science and technology. It is frequently argued that if we do not develop a citizenry which understands the scientific process we will find ourselves in a culture in which science is tolerated because of fear rather than respected because of understanding.

THE YEARS AHEAD

Are there things which we can point to in this our nation's bicentennial time which might foretell trends in science education during the years just ahead? It would appear that the U. S. citizenry, after a traumatic experience in an unpopular war and a difficult period leading up to and following the resignation of a president, has now developed a distrust for science and technology. As result of this, at this time and in this place, different types of science education programs should evolve. To predict changes there are quoted here a few paragraphs from an article I prepared for Indiana State University's *Contemporary Education*:

It is dangerous to try to predict changes in a field as diverse as Science Education. Therefore, it is done here with some hesitation. One change is fairly certain. There will be an increase in the use of individualized instruction. Audiotutorial modes of instruction will be more widely used. The student will be more frequently on his own, equipped with a learning package including audio tapes and equipment to complete an exercise or investigation. This may mean an increase in professionally-prepared or teacher-constructed kits. Films, film-loops, slides, and videotapes will become more common aids to learning in the individualized classroom. Self-pacing of learning activities will be more common.

The recent surge of interest in Environment Studies programs may reflect an alteration of goals. The 1960's appeared to reflect an over-emphasis on science as science. The recent Environmental Studies programs developed from an inter-disciplinary approach to real problems. The natural sciences are joined with the social sciences in attempts to solve environmental problems.

The Population Problem as a theme for study is another example of the cross-disciplines approach to Science Education. Earlier in time, so-called fused science curricula developed across science disciplines. As greater emphasis is placed on K-12 planning it is likely that some of the artificial boundaries established in and within science disciplines will vanish when local schools reassume their leadership role in curriculum construction. This return to local leadership is inevitable because of the ever-decreasing support for Science Education from the national level. The professional scientist may no longer be the leader of science curriculum projects.

There will be a trend toward human-centered science. Some decades ago we stressed the social implications of science. If one were to predict any one change for the 70's with certainty, it would be that science instruction will again emphasize the social implications of science. Young people have become disillusioned with accepting science for the sake of science. The majority of our youth has chosen not to be transformed into miniature scientists. Instead, they hope that science will become their servant instead of the reverse. They want to use their science to help to solve real problems in the social arena. Students want relevance and not intellectual gymnastics in their science courses. Therefore, we can expect to see a new problem-centered science

curriculum which addresses itself not to the problems of science but to the problems of man in his society. This will probably bring a new emphasis on technology as a source of illustrations for science problems.

Strong evidence for other changes is not available at this time. Nevertheless, the trends in Secondary School Science Teaching pose important implications for Science Teacher Education. The new breed of science teacher must know more about the content of his field. He must know how the subject matter of his field relates to problems in society. Also, he must learn how to function as a member of a team with teachers from other disciplines in bringing his expertise to bear on the real problems of people and their earth. He must be an innovator who has, in his undergraduate teacher education program, been given an opportunity to develop curriculum packages using multi-media. Most important, perhaps, he must have been given many opportunities in his teacher education program to pursue problems to their solutions using his own initiative. If the statement, we teach as we were taught, is true, then teacher education programs in the sciences must offer leadership to implement those changes (15).

So we observe over a period of about three and one-half centuries (1635-1976) many changes in secondary school science education in the United States. Many of these changes reflect a response of the system to the events of the time and the place.

REFERENCES

1. Atkin, J. Myron, and Burnett, R. Will. "Science Education." Robert L. Ebel ed. *Encyclopedia of Educational Research.* 4th ed. New York: Macmillan, 1969, pp. 1192-1206.

2. Bailey, Liberty H. *The Nature Study Idea.* New York: Macmillan, 1909.

3. Bellisario, Joseph. "E. Laurence Palmer: His Contributions to Nature, Conservation and Science Education." Ph.D. dissertation, The Pennsylvania State University, 1969.

4. Brandwein, Paul F.; Watson, Fletcher G.; and Blackwood, Paul E. *Teaching High School Science: A Book of Methods.* New York: Harcourt, Brace, and World, 1958.

5. Brubacher, John S. *A History of the Problems of Education.* 2d ed. New York: McGraw-Hill, 1966.

6. Caldwell, Otis W., and others. *Report of the Subcommittee on the Teaching of Science.* Bulletin No. 26. Washington, D.C.: U.S. Office of Education, 1920.

7. Comstock, Anna B. *Handbook of Nature Study.* Ithaca, N.Y.: Comstock Publishing Company, 1931.

8. Conant, James B. *On Understanding Science.* New Haven: Yale University Press, 1947.

9. Craig, Gerald S. *Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School.* New York: Teachers College, Columbia University Press, 1927.

10. Cubberly, Elwood P. *The History of Education.* Cambridge, Mass.: Houghton, Mifflin Company, 1948.

11. Dewey, John. *How We Think.* Boston: D. C. Heath, 1933.

12. Downing, Elliott R. "An Analysis of Textbooks in General Science." *General Science Quarterly* 12(1928):509-516.

13. Finlay, Gilbert C. "The Physical Science Study Committee." *School Review* 70(Spring 1962):63-81.

14. Fowler, H. Seymour. *Secondary School Science Teaching Practices.* New York: The Center for Applied Research in Education, Inc., Prentice-Hall International, 1964.

15. Fowler, H. Seymour. "Trends in Secondary Science Teaching." *Contemporary Education.* Indiana State University, 44(April 1973):267-270.

16. Frost, S. E., Jr. *Historical and Philosophical Foundations of Western Education.* Columbus, Ohio: Charles E. Merrill, 1966.

17. Hall, Thomas A., and others. "Science Teaching in Elementary and Junior High Schools." *Science* 133(1961):2019-2024.

18. Harvard Committee on the Objectives of a General Education in a Free Society. *General Education in a Free Society.* Cambridge: Harvard University Press, 1945.

19. Heiss, Elwood D.; Obourn, Ellsworth S.; and Hoffman, Charles W. *Modern Science Teaching.* New York: Macmillan, 1950.

20. Hurd, Paul DeHart. *Biological Education in American Secondary Schools 1890-1960.* Washington, D.C.: American Institute of Biological Sciences, 1961.

21. Hurd, Paul DeHart. *New Directions in Teaching Secondary School Science.* Chicago: Rand McNally, 1969.

22. Jackman, Wilbur S. *Nature Study.* National Society for the Scientific Study of Education, Third Yearbook, Part II. Chicago: The University of Chicago Press, 1904.

23. Klopfer, Leo O., and Champagne, Audrey B. "Six Pioneers of Elementary School Science." Project on the History of Elementary Science, Learning Research and Development Center, University of Pittsburgh, December, 1975.

24. Lockard, J. David (director). *Report of the International Clearinghouse on Science and Mathematics Curricular Developments, 1970.* Washington, D.C.: American Association for the Advancement of Science; College Park, Maryland: University of Maryland, 1970.

25. Marshall, J. Stanley, and Burkman, Ernest. *Current Trends in Science Education.* New York: The Center for Applied Research in Education, Inc., 1966.

26. National Education Association. Committee on College Entrance Requirements. "Report of the Committee on College Entrance Requirements." *Addresses and Proceedings* 38(1899):625-630.

27. National Education Association. Commission on the Reorganization of Secondary Education. *Cardinal Principles of Secondary Education.* Bulletin No. 35. Washington, D.C.: U. S. Office of Education, 1918.

28. National Education Association. Committee of Ten on Secondary School Studies. *Report of the Committee on Secondary School Studies.* Washington, D.C.: NEA, 1893.

29. National Society for the Study of Education. Committee on the Teaching of Science. *A Program for Teaching Science.* Thirty-First Yearbook, Part I. Chicago: The University of Chicago Press, 1932.

30. National Society for the Study of Education. *Science Education in American Schools.* Forty-Sixth Yearbook, Part I. Chicago: The University of Chicago Press, 1947.

31. Pack, Arthur N. (president), and Palmer, Laurence (director of Nature Education). *The Nature Almanac. A Handbook of Nature Education.* Washington, D.C.: The American Nature Association, 1930.

32. Progressive Education Association, Commission on Secondary School Curriculum. Report of the Committee on the Function of Science in General Education. *Science in General Education.* New York: Appleton-Century, 1938.

33. Shulman, Lee S., and Pinchas, Tamir. "Research on Teaching in the Natural Sciences." *Second Handbook of Research on Teaching,* Robert M. W. Travers, ed. New York: Rand McNally, 1973, pp. 1098-1148.

34. Smith, Herbert A. "Educational Research Related ence Instruction for the Elementary and Junior High School--A Review Commentary." *Journal of Research in Science Teaching,* Vol. 1. National Association for Research in Science Teaching, 1963, pp. 199-225.

35. Smith, Herbert A. and Anderson, Kenneth E. "Science." *Encyclopedia of Educational Research.* 3d ed. Chester W. Harris, ed. New York: Macmillan, 1960.

36. Underhill, Orra Ervin. *The Origins and Development of Elementary-School Science.* Chicago: Scott, Foresman, 1941.

37. Watson, Fletcher G. "Research on Teaching Science." *Handbook of Research on Teaching,* N. L. Gage, ed. Chicago: Rand McNally, 1963, pp. 1031-1059.

38. Woodburn, John H., and Obourn, Ellsworth S. *Teaching the Pursuit of Science.* New York: Macmillan, 1965.

Paul DeHart Hurd was born in 1905 in Colorado. He received his primary and secondary education in Colorado schools after which he attended Colorado State College of Education (now the University of Northern Colorado). He was awarded his A.B. in 1929 and his M.A. in 1932. His Ed.D. was awarded from Stanford University in 1949. Dr. Hurd was also awarded an Honorary Doctor of Science from Drake University in 1974.

Dr. Hurd served as a biology teacher and Department Head in Greeley public schools from 1929 until 1939 during which he also served as an instructor of biology at Colorado State College of Education during the summers. In 1939 he moved to California to Menlo School and Junior College where he served as a biology teacher and Chairman of the Science Department. He remained there until 1951 when he was appointed an Assistant Professor at Stanford University. He was appointed Associate Professor in 1955 and Professor in 1961. In 1971 upon his retirement Dr. Hurd was awarded the rank of Emeritus Professor.

Dr. Hurd has been active in professional organizations, including AAAS, AERA, AETS, NABT, NSSA, NSTA and NARST. He was elected a fellow of AAAS and served as president of NARST in 1971.

In addition to his duties at Stanford University Dr. Hurd serves on the science advisory committee to Educational Research Council of America, Chairman of the Policy Committee of the BSCS Human Sciences Curriculum Project, and Honorary Regent to the Communications Library in San Francisco. He served as Director of the Shell Merit Fellowship Programs conducted at Stanford University from 1959 until 1969.

Dr. Hurd has been an active researcher and writer throughout his career. His science curriculum books for elementary, junior high, and secondary science are widely used. His <u>Biological Education in American Secondary Schools 1890-1960</u>, which he is currently updating and revising, is a recognized historical documentation of the development of biological education. He has also been active as a consultant and coauthor of a number of textbook series.

Dr. Hurd's contributions to science education have been widely recognized. In addition to his honorary doctorate from Drake University in 1974, he was presented a NASA Apollo Award in 1970 and a Citation of Distinguished Service to Science Teaching from the NSTA in 1969, and was elected to Honorary Membership in 1976.

REFLECTIONS AND THE QUEST FOR PERSPECTIVES

PAUL DEHART HURD

Professor Emeritus
Stanford University
Stanford, California

Looking to the past profits us to seek clues to the future. It has always seemed to me that some notion of where we have been is essential when we are planning the future. As I read the research and literature on science teaching today I am amazed at how much is written about problems and issues that have already been explored--sometimes for a century. It is disappointing that these problems and issues are discussed ahistorically and in the absence of new insights, hypotheses, or methodologies which might offer promise for resolution. Furthermore, there is often a failure to recognize which problems and issues were time or context bound; in other words there is no reason for concern about these at this time. It is this latter condition that limits the value of looking to the past for insights into the future. With these cautions in mind I shall risk looking back with the hope it will stimulate perspectives for the future.

This is a critical time in science education. Since 1968 changes in our society and in cultural conditions have had a far-reaching influence on our lives and our schools. These changes have been so rapid and of such magnitude that Kenneth Boulding has described this era as a "cultural mutation." Who among us sees the world of 1976 to be like that of 1968?

Science as an enterprise has also undergone changes. It has become inextricably woven into the fabric of society and government. Research and development in science has moved from the "ivory tower" to the marketplace. Research problems in science now arise as much from social and technological demands as from the evolving character of the discipline. The social and economic problems of energy, population, natural environment, quality of life, human habitat, transportation, communication, health, world food supply, and others are recognized as concerns for scientists. Distinctions between science and technology are ever harder to make. As we look back over the past 25 years we see a great period of technology, but less so of science. Biological sciences are the exception. The early 1950s saw the rise of molecular biology and reductionism. Twenty

years later we find the emphasis is on human sciences, ecology, and holism. Witness the number of new books on human ecology, human biology, sociobiology, bioethics, psychobiology, biogeography, and environmental biology. Only by looking to the past can we appreciate the magnitude of these changes within a single discipline. What should concern science educators is that these discipline changes also influence the whole educational context in which a science ought to be taught. What do these shifts in a discipline mean for teacher education in science?

SCIENCE TEACHER EDUCATION

I have often stated over the past several decades that we do not truly have a science teacher education program in America. The college or university major for science teachers is not typically based on a content analysis of school science curriculum, or in other words, what a teacher is expected to teach. The pattern of science courses for a teacher is oriented toward a career as a researcher in science. To be sure, most of these courses are good science; the issue is that many of them are not needed for teaching school science and the time could be spent on courses a precollege teacher of science needs.

What subject matter should be included in the education of a science teacher for the 1980s? Certainly in the pattern of courses substantial time should be devoted to:

1. The history and philosophy of science including case studies of critical events in science and their ultimate expression in technology.
2. The sociology of science including an exploration of the relationships between science, technology, and public policy.
3. Science and culture with a focus upon current ethical and moral questions which involve science and scientists.
4. Something of the art, tactics, and strategies of scientific investigation as well as an understanding of decision-making processes.

Without this background I see little possibility of a science teacher achieving such educational goals as "scientific literacy," "appreciation of science," "understanding the processes of science," "the social role of science," or the "personal use of science."

It seems to me quite evident that the emerging goals of science teaching are oriented toward the worthy *use* of science based knowledge to improve the quality of human life and living. The social and personal use of science cannot escape moral, value, and

ethical issues. The "process" skills that go along with this approach to science teaching are so closely identified with decision making and cybernetics as with scientific inquiry and discovery. Courses involving science, technology, values, and society have drawn their substance from both the natural and social sciences. This suggests an integrative and unified approach to science teaching. For the most part beginning science teachers do not have this background and are therefore condemned to teaching only the nomenclature of a science. Although science has both a cognitive and social dimension most teachers are prepared to teach only the cognitive phase.

As I look back at the professional training of science teachers I find no course on the psychology of learning with topics appropriate to the kinds of learning expected in science courses, such as attaining concepts, achieving problem-solving skills, developing attitudes and values. This is not to imply that there is a special psychology of learning for science but rather there are topics particularly relevant to science teaching that should be isolated and taught with exemplars from science curricula. Charles Hubbart Judd, 1922, in his *Psychology of High School Subjects* introduced the idea but the appropriate textbook was never written (3). In frequent surveys of teacher education programs we find student teacher's listing their course in educational psychology as largely irrelevant to the teaching of science--how could this be?

Another lack in teacher education is adequate attention to the research on science teaching. The classroom teacher should be a prime consumer of educational research in some direct way; after all, the stated purpose of much of the research is either to improve instruction or to develop more effective curricula. I think it is fair to state that we have not yet developed an affective means for moving the products of educational research to the intended consumer. In addition, the professional teacher should be able to participate in research on science teaching. I fear that over the past 15 years more time and money were spent attempting to make science teachers amateur scientists than researchers in their own profession.

I see the science teacher as an interpreter of the scientific enterprise and as an expert on learning, dedicated to enlightening young people in ways that they can use their knowledge of science for rational decision making. I do not see the science teacher as a person whose responsibility it is to advance the conceptual or theoretical structure of a discipline--this is the work of th research scientists. The principal claim of science teachers to importance is their capability for teaching science. Their leadership should be measured by their contributions to curriculum and to instructional procedures. Their contributions to research should be those of advancing the teacher-learning process.

THE CHANGING SCIENCE CURRICULA

There appears to be a reluctance to foster changes in science curricula; the result is they soon lag behind cultural demands. The subject matter is usually brought up to date from time to time but there are relatively few changes in the rationale for the selection of the subject matter or the design of the curriculum. Rationale, goals, and objectives are restated at intervals by committees appointed to do so. Rewriting goals and objectives has become largely a ritual rather than a serious consideration of

1. Deeper educational insights.
2. Cultural shifts.
3. Changes in school policies.
4. New research into learning.
5. Improved educational technology.
6. Milestones in the conceptual structure of science and the evolving nature of the scientific enterprise.

The science education community was brought to task for some of these neglects in the 1950s when the federal government asked the National Science Foundation (NSF) to reconceptualize and update precollege science curricula. Possibly the greatest accomplishment of NSF was to make change and innovation respectable in science teaching.

We are now at a time where there is need for a serious redirection of science teaching. We have had crisis periods before in science teaching, some of which are reflected in the following reports and events: 1798 (the Dupont de Nemours report); 1860 (vocational agriculture); 1895 (the NEA report); 1905 (influence of mass immigration); 1913 (impact of industrialization); 1920 (cardinal principles of education); 1935 (progressive education movement); 1945 (Harvard and Truman reports); and 1958 (the "cold war" and NSF). In each of these periods the crisis was stimulated by a swell of public ferment about what the teaching of school science should accomplish. The time for change was signaled by serious social and economic dislocations, new achievements in science and technology, or some combination of these factors, all serving in varying degrees to focus the need for a new look at the science curriculum. It seems to me that the signals for a science curriculum reform were never clearer than they are at this moment, 1976. Witness the "need" and "assessment" projects of NSF and its efforts to identify the emerging rationale for precollege science teaching.

The turmoil of events and conditions in our society and in science and technology are of such magnitude and variety that we are undoubtedly undergoing the greatest transformation in history.

The impact of these forces on human existence exceed those caused by the introduction of fire, or agriculture, or industrialization, or technology at other periods in human history. It is not possible here to describe the many shifts in our culture but a few examples are essential. Consider for example that now for the first time in history human beings control their own evolution and adaptive capacity. The reach of science and technology extends into nearly all human activities and may well be the critical factors influencing the survival of the human species. Already the changing foci of interests in scientific research and technological innovation are apparent. Herein is the context for the problems and issues which the teaching of science must recognize for at least the rest of this century. Herein also lies the challenge for the need to conceptualize and invent a new science curriculum.

There is no doubt that a science curriculum designed to foster a favorable evolution of human beings, to enhance the quality of human existence, and to improve the adaptive capacity of human beings is a tremendous challenge. What characteristics is this emerging science curriculum likely to have? Enough has happened to indicate a few perspectives and enough curriculum development has taken place to demonstrate their feasibility. Only a few issues and perspectives can be identified here because of limited time and space; documentation and elaborations will be reported elsewhere.

- Scientific literacy (more correctly enlightenment) needs to be redefined to reflect the current science/social scene and our expectations for the future. Present descriptions of scientific literacy are discipline bound and do not represent the reach of science and technology in modern society and in cultural evolution.
- It is becoming increasingly clear that science teaching should be oriented toward the *uses* of science to resolve science based societal problems and issues (such as environmental outrages, overpopulation, energy, health delivery systems, quality of living, and a host of other problems). (Note the program for the 1976 American Association for the Advancement of Science--AAAS--annual convention and those for the past four years.) This means, among other things, less time devoted to teaching the skills in scientific inquiry and greater attention to processes of information retrieval and to decision making. It also means the teaching of science in a human and social context rather than for illustrating the theoretical and conceptual structure of scientific disciplines. Furthermore, it means an emphasis upon the unity of science and the teaching of science in an integrative mode. Consider, for example, the direction research and curriculum development in biology are taking in this regard. In the past few years we have seen the

rapid growth of such sciences as psychobiology, biophysics, biochemistry, sociobiology, human ecology, biogeography, bioengineering, population and environmental biology, and bioethics, in addition to renewed interest in human evolution and human behavior, and holistic approaches to research and the interpretation of information in terms of integrative conditions. Emerging from this complex we see the development of a human science or a science of human systems.

- The educational limitations of the traditional laboratory exercises, devoted almost exclusively to preprogramed experiments of limited applicability outside the laboratory, are becoming apparent. These experiments are too simplistic to simplify a curriculum with a science/societal orientation. The anticipatory, cybernetic, clinical, and participatory (in the cultural anthropologist's or sociologist's sense) investigations are all more closely related to the "real life" activities of people than those which are wholly laboratory bound.
- Science has been taught throughout its history as a value-free enterprise. For generating knowledge there is support for the notion though many scientists doubt that science was ever as value-free as its interpreters have stated. Recently, however, society and circumstances have brought the scientific community into a position where it is pressured to consider moral, ethical, and value questions arising from its endeavors. For the nonscientists who make use of scientific information science is never value-free. Science taught in a personal/social context deals with human problems and issues that a knowledge of science alone is insufficient to resolve. Rational decision making uses facts but their interpretation is subject to bias, prejudice, and preference as well as earnest convictions, moral commitments, and ethical convictions. Furthermore, when scientific information is carried into social action its meaning is likely to be influenced by cultural context, historical perspective, and political circumstances. A fact leaves the scientist's laboratory precisely described and little more. To convert this fact to public use or intelligent human action is another matter, almost wholly neglected in pre-1976 science curricula.
- In the 1950-1960s science curriculum movement the study of technology was considered inappropriate although we live in an era most frequently described as the "age of technology." The interrelation of science and technology was seldom identified and when this did happen the meaning of technology was misinterpreted as machines

and gadgets. Technology is an endeavor which has made it possible for people to capture nature and the resulting social consequences were not goals of the discipline-bound science curricula. Neither was the use of technology to extend the adaptive capacity of human beings considered worthy of study. The innovative science curricula of the 1970s, and rightfully so, are distinguished by an interweaving of science, technology, and values.

These goals and themes illustrate but do not completely identify the emergence of a new rationale and framework for the teaching of science--one that considers the cognitive and social structure of science. Unfortunately it is not possible here to fully develop these ideas and to provide the data that brought them into at least a partial focus. The sixth and earlier editions of the AAAS volumes on *Science for Society* provide a source of reference for further elaboration (1, 2, 4, 5, 6, 7). Lest I be accused of describing a curriculum platform that cannot be implemented let me indicate that progress has been made and courses of study are becoming available; a representative list will be found at the end of this chapter (pages 116-117).

It is obvious that these goals for science teaching make new and far-reaching demands upon the education of science teachers. This just may be the most propitious time for the Association for the Education of Teachers of Science (AETS) to propose and define in detail a set of guidelines for teacher education in science that is consistent with emerging perspectives for science teaching. Such an endeavor will demand considerable study to amplify and clarify the philosophical basis for the new perspectives and to justify their discontinuities with the past. Any statement of rationale and goals should be followed by a rigid deduction of their consequences for curriculum, instruction, learning, evaluation, and other teaching components. We need to be confident of what we plan to do and why we plan to do it this way. I am arguing for a disciplined approach to perspectives for science teaching in contrast to casual reflections based upon current educational slogans and fashions and unrefined extensions of traditional goals and conventional thought. We need a rationale and set of goals that can answer the critics of science teaching whoever they may be, lay or professional.

IN-SERVICE EDUCATION

Crucial to curriculum reform in science for the years to come will be the development and acceptance of effective in-service programs in schools. Several years ago (BSCS--1972) I reviewed a broad sample of the literature on the diffusion and implementation

of innovative science curricula as well as studies in other fields where the introduction of new practices is a problem--for example industry, medicine, business, agriculture. It is apparent that bringing about any kind of planned change in American social institutions is difficult whether it be schools, health delivery systems, environmental improvements, or whatever. Our knowledge of how purposive social and educational change takes place is sketchy and we are in need of extensive research on the topic. Finding effective mechanisms and identifying the social conditions needed to bridge the gap between the educational researcher, the curriculum developer, and the ultimate user (the classroom teacher) are yet to be resolved. Perhaps the gap might not be so great if teachers were more closely involved in curriculum development and research.

Over the past 15 years $530 million has been spent by NSF alone to "up-grade" (a horrible term) science and mathematics teachers to effect curriculum reform. Institutes and a variety of other programs were initiated for this purpose. I do not wish to argue the success of these programs but rather to point out that such an effort at government expense is *not* likely to occur again. This raises several issues: Is there not a moral responsibility in any profession for its members to keep current with new developments? Is it not a responsibility of the professional science teacher to test new curricula and instructional materials and to ascertain their value for improving the effectiveness of education? I am disturbed by the all too many science teachers and union representatives I meet who feel that they cannot be interested in self-development and educational progress unless "paid extra." Be this as it may it is clear that a well-conceived system of in-service education, or perhaps a better term would be "career development," is needed to introduce new curricula and instructional materials into schools.

I feel now is an opportune time to initiate creative in-service programs. Some of the conditions that make this a reasonable statement are:

1. There are a growing number of demands on schools to meet the educational challenges that face them, including new curricula.
2. With the surplus of qualified science teachers administrators can be pressured to select those who are professionally minded and socially aware.
3. Educational innovations are more easily introduced during a crisis period, be it economic, social, professional, political, or academic in its origins.

The problem is to create in-service programs that are of sufficient intellectual quality to stimulate professional growth. The program should be rich in cultural foresightedness to enable the imaginative teacher not only to keep abreast of educational change but to be assured of meaningful educational progress. The difficulty of this task is awesome, but dare we strive for lesser ends? Do we plan the future of our field or do we settle for the status quo and default to the inertia that has plagued the educational enterprise for centuries?

A NOTE IN CONCLUSION

People asked to recollect happenings in history tend to glorify the past ("things aren't like they used to be") and to take a dim view of the future ("what's the world coming to"). I see the past as time and context bound wherein the unique conditions (educational, psychological, social, political, cultural, economic, scientific, technological) make one approach to science teaching more acceptable than another. As the pattern of conditions changes new curricula and new programs of teacher education become imperative. The time interval between these educational watersheds has in the past been approximately 50 years. Today human systems change so rapidly (sometimes by orders of magnitude) and divergently that the optimum life of an educational program is probably not much more than a decade. Our inability to respond incisively to educational dysfunctions is in part the result of:

1. A collective inertia and resistance to change within the educational enterprise.
2. A tendency to freeze an established curriculum by an overcommitment to conventional rationale, goals, and subject matter. For example, we <u>re</u>-think the rationale, <u>re</u>-state the goals, <u>re</u>-assort and <u>re</u>-align the subject matter but tend not to create what is needed to meet the challenges of a new era in human history.
3. An unawareness of the scale of change taking place in the world today.
4. A lack of a clear notion of what a liberal education in the sciences means. For example the science curriculum reform of the 1960s sought to have young people understand the theoretical and conceptual structure of various science disciplines and to become skillful in their investigative procedures. Is this liberal education or vocational education?
5. A poorly conceptualized theory of curriculum. Only in the past several years has curriculum theory begun to emerge as a field of scholarly study.

6. A lack of change mechanisms in schools, particularly reward systems for teachers, by which creative ideas and innovative practices are sought and their validity tested.
7. A failure to study the future before planning educational change.

What should our reflections on past practices in science education accomplish? I hope we could achieve an aversion to the continuous recycling of educational policies and mechanisms which we know through research, practice, and philosophy to be inadequate for contemporary human needs. I feel the severest criticism of educational practice is that "the pendulum swings back and forth." The 1960s are not the 1970s and the 1970s will not be the 1980s or the 1990s--hopefully the science curriculum developer and the teacher educator will foresee, keep pace with, and lead in changes which represent progress toward a higher order of science teaching.

COURSES OF STUDY FOR CURRICULUM

Biological Sciences Curriculum Study. *Human Sciences Program.* Boulder, Colo.: BSCS, in progress.

Braun, L. (director). *The Huntington Two Project.* Stony Brook, N.Y.: College of Engineering, State University of New York, in progress.

Burkman, Ernest (director). *Individual Science Instructional System.* Tallahassee, Fla.: The Florida State University, in progress.

Damaskos, N. *You and Technology: A High School Case Study Text.* Chester, Pa.: PMC Colleges, 1969.

Educational Research Council of America. *Unified Science Program.* Cleveland: Educational Research Council of America, in progress.

Engineering Concepts Curriculum Project. *The Man-Made World.* New York: McGraw-Hill, 1971.

Holton, G.; Rutherford, F. J.; and Watson, F. G. (directors). *Project Physics.* 2d ed. New York: Holt, Rinehart and Winston, 1975.

Hughes, Leonard (director). *The Biomedical Interdisciplinary Curriculum Project.* Berkeley, Calif.: University of California, in progress.

Hurd, P. DeHart; Berman, N. L., and LaRue, C. *Biology: A Human Approach.* New York: McGraw-Hill, in progress.

Lomon, Earle L. (director). *Unified Science and Mathematics for Elementary Schools.* Newton, Mass.: Education Development Center, in progress.

Materials and Technology Curriculum Project. Seattle: Department of Mining, Metallurgical and Ceramic Engineering, University of Washington, 1973.

Truval, J.; Piel, J., and Liao, T. *Technology ↔ People ↔ Environment.* New York: Learning Realities, 1976.

REFERENCES

1. Bausum, Howard T. *Science for Society: A Bibliography.* 3d ed. Washington, D.C.: American Association for the Advancement of Science, 1972.

2. Dasbach, Joseph M. *Science for Society: A Bibliography.* 6th ed. Washington, D.C.: American Association for the Advancement of Science, 1976.

3. Judd, Charles H. *Psychology of High School Subjects.* Boston: Ginn & Company, 1922.

4. Moore, John A. *Science for Society: A Bibliography.* Washington, D.C.: American Association for the Advancement of Science, 1970.

5. Moore, John A. *Science for Society: A Bibliography.* 2d ed. Washington, D.C.: American Association for the Advancement of Science, 1971.

6. West, Felicia E. *Science for Society: A Bibliography.* 4th ed. Washington, D.C.: American Association for the Advancement of Science, 1973.

7. West, Felicia E. *Science for Society: A Bibliography.* 5th ed. Washington, D.C.: American Association for the Advancement of Science, 1974.

Philip G. Johnson was born in 1900 in Nebraska where he received his elementary and secondary education. He was awarded his B.S. in 1923 from the University of Nebraska. In 1925 he went to the University of Minnesota for a year of graduate study, returned to the University of Nebraska as a staff member, and completed the requirements for his M.S. in 1931. He was awarded his Ph.D. from Cornell University in 1933.

Dr. Johnson taught secondary science and mathematics in Nebraska from 1923 to 1925. He served as a supervisor of science at Teachers College High School, University of Nebraska, between 1926 and 1931, and after completion of his Ph.D. in 1933 he was appointed Assistant Professor and Supervisor of Science at the University of Nebraska. In 1935 he was appointed Assistant Professor of Science Education at New York State College of Agriculture of Cornell University and a high school science teacher in Ithaca public schools, positions he held until 1946. From 1946 until 1953 he worked with the USOE, Division of Elementary and Secondary Schools, as a Specialist for Science. In 1953 Dr. Johnson returned to Cornell University as Professor and Director of Science Education. He was named Emeritus Professor of Science Education in 1967.

Dr. Johnson has been active in AAAS, NSTA, AETS, NEA, and Science Teachers of New York State. He served as president of NSTA from 1944 to 1946, secretary-treasurer of the New York State Science Teachers Association from 1938-1941, and president in 1945. He was president of the Department of Science Instruction of the NEA in 1942.

In addition to his regular science education responsibilities at Cornell University, Dr. Johnson served as Director of Shell Merit Fellowship Programs from 1957 until 1968 and as Director of several NSF Teacher Research Participation Programs between 1959 and 1963. He was a Fulbright Lecturer at Catholic University and the University of Chile in 1966-1967 and a Ford Foundation visiting professor in 1969-1972.

Dr. Johnson has been an active author and researcher. His articles have appeared in many science education and education journals and in U.S. Department of Health, Education and Welfare publications. He served as junior author for the <u>Modern Science</u> series for junior high school.

Dr. Johnson was given a Recognition Award from the Science Teachers Association of New York in 1947 and the Centennial Award in Science Education from the Canadian Science Teachers Association in 1967. He was awarded a Distinguished Service Award by the NSTA in 1970.

SOME REVOLUTIONARY CHANGES IN SCIENCE EDUCATION: 1850 TO 1950

PHILIP G. JOHNSON

Professor Emeritus
of Science Education
Cornell University

This paper calls attention to some major changes in precollege science course content and related instructional practices during a 100-year period. The period 1850 to 1950 was selected because several very fundamental changes did occur in that interval. Many of the changes may be overlooked due to the startling developments that have occurred since 1960. As we consider our Bicentennial we should be aware of the deep roots that have shaped and which continue to modify our science education programs.

Our common schools began more than 200 years prior to 1850. Leaders among the founding immigrants had a deep respect for education and lost no time in providing some formal schooling for their children. They carried ideas about what would be proper contents and methods with them from Europe. Preparation for church functions as well as for local, state, and national leadership caused these early leaders to include the writings of Latin and Greek scholars. Through such studies their children could learn the proper form for their own writing while they became imbued by the philosophy and ethics emphasized in the classical and revered literature.

The formal educational opportunities for youth as this science education chronicle begins were: common schools, grammar schools, graded schools, upper schools, union schools, high schools, academies, preparatory schools, and preparatory departments of colleges and universities. Academies were giving way to public schools and some of them became free academies. Some youths were going from public high schools directly into colleges. Although a favorable determination of the legality of providing high school opportunities at taxpayer expense did not come until 1874, the issue had been settled well before that event.

> By 1857 the principle of maintaining high schools at public expense had been thoroughly established in practice. Encouraged by ambitious teachers, older pupils studied subjects of a more advanced nature than those in the

> common-school course. Parents were delighted to have their children study these advanced subjects hitherto taught only in academies. Step by step the schools added subjects and then whole years to the program, and the high school had arrived--a growth, a process, and an evolving institution--not a separate creation. The battle over high schools never involved the question of authorizing them; they already existed. The issue was over their maintenance and continuation. State after state evolved the legal theory that high schools were simply the higher subjects of the common school, and the theory became law (63:11).

The type of preparation that was expected from the high schools may be seen from the areas that were examined in the process of students being selected for college. In 1958 Harvard indicated that there would be examinations in mathematics, history, geography, Latin, and Greek. While the elementary schools provided only incidental science lessons the high schools often offered one or more of: natural philosophy, chemistry, physics, geography and natural history, botany and zoology. Two descriptions indicate the nature of the science work around 1850. The first one was given by Paul J. Fay in an extensive report on chemistry.

> During the first three-quarters of the nineteenth century, chemistry teaching was superficial, but rather practical. . . . The most obvious features of high school chemistry during the first period were its informal character, its utilitarian nature, its superficiality and the memoriter character of the teaching methods. . . . The method of teaching used throughout this period was predominantly that of assigning material in the textbook and hearing the pupils orally repeat the same material (13:1533, 1546).

Bigelow discussed the natural history work as follows:

> We can best understand the present natural history in secondary schools after briefly reviewing the history of formal instruction concerning animals. From the earliest records of such teaching in the last part of the eighteenth century until sometime in the eighties of the nineteenth century, the common instruction was along the lines of the old natural history, consisting chiefly of descriptions of external forms, life histories, classification and relations of animals to man (30:265).

THE OBJECT METHOD:
OUR FIRST REVOLUTIONARY CHANGE

It was in 1858 that Edward A. Sheldon made his trip to Toronto and "returned from this visit with the delight of the discoverer of a new world, laden with charts, books, balls, cards, pictures of animals, building blocks, cocoons, cotton balls, samples of yarn and specimens of pottery and glass" (16:17). The enlarged vision caused him to offer new courses at Oswego, New York. In these new courses he dealt with form, color, size, weight, animals, plants, the human body, and moral instruction. The demonstrations that so challenged Sheldon were from the Home and Colonial School in London. He brought the key instructor from this school to Oswego Normal School and later he also brought another Pestalozzian to help develop the Object Study Method. Sheldon and his coworkers brought about a new direction to American education by extensive lectures, demonstrations, instruction, and written materials, including in 1963 a book *Lessons on Objects* (51). The Object Study Method successfully challenged the listening, note taking, reading, and rote reciting so prevalent at common school levels. It also came to have a very profound influence on high school and college studies where giving lessons, assigning reading, hearing lessons, and giving tests were the common instructional practices. It was a small step from object study to nature study, field work, laboratory work, demonstration methods, and an approach to teaching and learning which removed the textbook and the teacher from the preeminent position as the source of all truth. In 1882 the Department of Interior, Bureau of Education, issued a bulletin with the following statement:

> Instruction in natural science should be a training in thinking. Pupils should be led to form general ideas and laws from the objects of study and the phenomena presented to them, to draw conclusions upon the causes of such phenomena and predict the future action of the causes they have learned to know. In this way not only a knowledge but also an understanding of nature is reached. . . . The natural science school book should be used only as a book of reference in reviewing, as a means of saving writing, for recalling to memory the things observed in the course of study, as a help in looking up modes of expression, and particularly as a general model. No repeating from memory things not observed by the students themselves and no mere reproduction of school book information should be asked for either in the examinations or by inspectors (59:5, 7).

It is difficult to document the influence of the Object Study Method on secondary and college science teaching or to justify a statement that the influence was unique and profound. One statement by Edwin H. Hall, an eminent Harvard physics professor, bears on the influence.

> On the whole, it appears that the best secondary schools in America, in trying the experiment of teaching physics by means, in part, of laboratory work done by the pupils, have little or nothing to learn from the corresponding schools in France, Germany, or England. For France has apparently never dreamed of such an undertaking, Germany has never seriously considered it, and England is no farther along with it than we are in America, if indeed she is as far (52:370-371).

ATTEMPTS TO CONTROL CURRICULA: OUR SECOND REVOLUTIONARY CHANGE

The academies that flourished around 1850 were under the control of their benefactors, their boards of managers, their headmasters, and their teachers. In their early years they provided much practical instruction along with some classical preparation. More and more they began to serve a college preparatory function. Those academies that became known for excellent college preparation required examinations for admission and graduation. Their success came to be measured by the success of their graduates in gaining admission to their selected colleges and by the progress that the students made during and after college. Many but not all academies became very responsive to the expectations of the colleges.

The public high schools were first and foremost responsible to their elected boards of education, their chosen school leaders, and the teachers. As more and more youths extended their education into the public high schools the offerings and instructional practices changed more and more to meet the needs and interests of the broadening spectrum of youths. Diversity became a greater and greater problem when these public high schools were called upon to serve a larger and larger number who had collegiate studies in mind. The problem became intolerable to many college admission officers and the collegiate teaching staff. In their judgment something had to be done.

New York established a Board of Regents and state examinations for graduation. Examinations were based on syllabi which were issued for the guidance of teachers and school leaders. The Regents Plan was established in 1877 and the first syllabus was made available in 1880 (43). From that time syllabi have been revised from

time to time and examinations have been developed and used in support of a New York State Regents Diploma. Many other states have issued syllabi under the general title of courses of study but very few developed an examination system and only New York has maintained such a system.

The University of Michigan accepted botany for admission in 1873 and Harvard University accepted physics for entrance in 1886 (11). As a guide to the schools Harvard made available descriptive lists of experiments and outlines of topics deemed to be suitable preparation for admission. The lists from Harvard for physics appeared in 1887 and in 1897. The lists for chemistry were first available in 1888. These lists were notable because they represented the first attempts to lay out descriptions of suitable laboratory work.

> The influence of the Descriptive List on the development of physics teaching in America has been tremendous. It appeared at the psychological moment when the demand for object teaching, which had made its appearance here about 1848, had reached its full force. It exalted this demand for object teaching into a requirement of quantitative laboratory work. It showed teachers and school boards how a laboratory method of teaching could be introduced into the work in physics with the use of materials at hand and with a small outlay for equipment (33:58).

Another avenue of control was through committees established by organizations of national repute. In 1884 the United States Bureau of Education published a bulletin that contained a suggested list of topics to be considered fundamental to a course in physics (61). This was followed in 1887 by a report from a committee of college and high school physics teachers appointed by the National Education Association (NEA) and the American Association for the Advancement of Science (AAAS). Their report contained the following statement:

> Your committee on physics teaching was appointed in 1885 to consider with disparagement of other studies linguistic or scientific, how physics teaching in our schools may be improved and made more uniform throughout the country.
>
> We believe it would tend to improve the teaching of physics and would promote a helpful degree of uniformity, if all the teachers of this branch of science would unite on a list of subjects that should be regarded as fundamental---never to be omitted from a high school course, however many others may be added to them---and always to be taught by experiment. Such a list we give below; it will serve at least to indicate the class of subjects

which we think should be included in the high school course, and, we hope, will lead to examination and discussion, and later to the adoption of some similar list (38:41,43).

The final links in the chain used to control school curricula began to be forged when the National Council of Education, a creation of the NEA appointed the Committee of Ten on Secondary School studies in 1892. There were nine subcommittees or conferences each with ten persons. Of the persons serving on these conferences, 75 percent were either college staff members or headmasters of preparatory schools. They gave their attention to the courses that colleges recognized for admission. Three conferences were concerned with the sciences: 1. physics, astronomy, and chemistry, 2. natural history including botany and zoology, and 3. geography including physical geography, geology, and mineralogy. Their report in 1893 served to confirm with only minor variations the earlier descriptive lists of experiments and topics (39). Then in 1899 the Committee on College Entrance Requirements reaffirmed these descriptions (37). By these actions and by a system of accreditation of high schools by visiting teams the high schools were influenced to half or at least to limit their curricular innovations.

SCIENCE TEACHERS ORGANIZE AND RESPOND: OUR THIRD REVOLUTIONARY CHANGE

High school science teachers were a minority of those who had a part in attempts to control high school curricula. Many of those who became members of the committees shared the views of the college staff members. But ideas about the purposes of high school studies and about adolescence were changing and some of the high school science teachers felt strongly the limitations that the college orientated leaders had placed on the high school levels. One of the more articulate of these persons was C. R. Mann of the University of Chicago. In a tract published in 1906 he wrote:

> In sharp contrast with the growing popular interest in the work of science stands the enthusiasm of the rising generation toward its study. In an article in the *Educational Review* for March, 1906, Prof. J. F. Woodhull describes forcefully the change for the worse that has taken place in the past twenty years in the attitude of the school children toward the study of physics.
> The same facts are clearly presented by G. Stanley Hall in his work on *Adolescence*, Vol. II, p. 154. They are very familiar facts to all high school principals, college deans, and others who are in a position

> to hear the students frank and unvarnished expressions of opinion concerning their own work.
>
> Since these facts have come into great prominence in the last few years, it becomes a matter of necessity to try to diagnose the disease, and to attempt to discover the pathogenic bacteria that are responsible for it. Investigations into the nature and habits of this comparatively new species of bacteria have disclosed the fact that it is not indigenous to physics teachers. Before his classes begin to notice that a teacher shows symptoms of the blasting disease he must be innoculated by the agents of the Association for the Prevention of Enthusiasm among Students. The innoculating fluid is especially prepared for the association by a corps of trained college examiners and technical physicists, and is warranted to be pure stuff and certain in its operation. The formula for the preparation of the serum is as follows: Take 30 parts of desiccated mathematics and grind well together with 20 parts of pure abstraction. When thoroughly mixed, stir in 10 parts each of accurate measurement, technical manipulation, notebook compilation and percentage of error. Let stand over night. Then add 8 parts of definitions of the undefinable and 2 parts of real physics. The solution must be carefully corked up in college entrance examination bottles, since it spoils quickly when exposed to the fresh air and sunshine of the world about it (32:2-3).

He continued to discuss his feelings and included a lengthy section from the article mentioned under the authorship of Professor Woodhull. Similar feelings must have motivated other teachers to join with them in forming an organization of physics teachers in the Chicago area in 1902. Later that year teachers of high school biology, chemistry, earth science, and mathematics were included in the formation of the Central Association of Science and Mathematics Teachers (CASMT). Earlier by a few years, in 1895, a group of high school and college science teachers had formed the Department of Natural Science Instruction of NEA. In New York state the science teachers established their association in 1896. Similar groups were formed in other states and in cities for the purpose of developing an effective voice for the views of high school science teachers on curricular and instructional problems.

In 1908 a commission met in New York City to prepare a new definition of requirements for a course in elementary physics. A vigorous minority report dissenting from the views of the majority was handed in by the representatives of the North Central Association. This minority urged that the definition should be referred to successful and experienced teachers of physics who were actively

engaged in teaching this subject at high school levels. This idea prevailed and the definition that they produced was accepted by the College Entrance Examination Board (CEEB). This influence of active high school science teachers increased more and more until the college specialists came to perform a cooperative or an advisory function in the definition of high school science curricula. However, a strong influence by collegiate scientists has continued over the years but it has been tempered by the views of active high school science teachers.

THE NATURE STUDY MOVEMENT: OUR FOURTH REVOLUTIONARY CHANGE

The Object Study Method produced a major change in instructional practices, especially at the lower common school levels. But it also laid firm foundations for the nature study emphasis which had not only a profound effect on elementary school science but also on field and laboratory approaches to science at higher levels. While the Object Study Method brought an instructional revolution it also reduced attention to the exotic and fanciful studies which were in some school lessons. However those with a scientific point of view wanted a well-arranged science course of study at elementary school levels. William Torrey Harris published such a program for the St. Louis Schools in 1871 (15). He was a vigorous school leader who became president of NEA in 1874. He strongly promoted his artificial spiral design for science lessons. For 20 years his gained wide acceptance.

Naturalists were not happy with such an artificial arrangement. Gustave Guttenberg reported that in 1890 the American Society of Naturalists had developed an alternative.

> There is a committee existing. . . . This committee has been appointed by the American Society of Naturalists to consider the subject of science in the schools. It has submitted a report, which has been accepted by the Society. The propositions of this report, as far as they concern primary and grammar schools are as follows: (1) Instruction in natural science should commence in the lowest grades of the primary schools and should continue throughout the curriculum. (2) In the lower grades the instruction should be chiefly by means of object lessons; and the aim should be to awaken and guide the curiosity of the child in regard to natural phenomena, rather than to present systematized bodies of facts and doctrines (14:596-7).

A nature study program was about to be launched in Pittsburgh in 1889 where W. S. Jackman, a Harvard graduate, had spent five years developing such a program while serving as a high school teacher. At this point he had an opportunity to take charge of the science work at Cook County Normal in Chicago, succeeding a teacher from Oswego Normal School. Jackman perfected his nature study program and spread his plan widely through his teaching, lecturing, and writing. Several publications appeared in 1891, 1894 and 1901 (25, 22, 23). *Nature Study*, the Third Yearbook of the National Society for the Study of Education (NSSE), Part II, 1904, was devoted to his nature study plan with Jackman as the author (21). Jackman suggested a seasonal arrangement of topics rather than a study of types. He stressed direct observation followed by personal interpretation while the program by Harris stressed lectures and experimentation by the teacher.

In the 1890 to 1910 period several ideas about a nature study program appeared. Two have persisted over the years. One was the nature garden idea. This was explained and promoted by Arthur C. Boyden (2). It prospered and nature gardens persist in some school settings to the present time. Another idea about nature study was expressed by L. H. Bailey in 1897.

> Nature-Study, as a process, is seeing the things that one looks at, and the drawing of proper conclusions from what one sees. Its purpose is to educate the child in terms of his environment, to the end that his life may be fuller and richer. Nature-study is not the study of a science, as of botany, entomology, geology, and the like. That is it takes the things at hand and endeavors to understand them, without reference primarily to the systematic order or relationship of the objects. It is informal, as are the objects which one sees. It is entirely divorced from mere definitions, or from formal explanations in books. It is therefore supremely natural. It trains the eye and the mind to see and to comprehend the common things of life; and the result is not directly the acquiring of science but the establishing of a living sympathy with everything that is (6:11).

Bailey as director of the College of Agriculture at Cornell University in Ithaca, New York, continued to influence this type of nature study. He enlisted the help of many faculty members and they wrote leaflets in their area of specialization but with the nature study philosophy. A collection of the leaflets between 1897 to 1904 was reprinted under the title of *Cornell Nature-Study Leaflets* (6). Bailey was the author of 17 of these leaflets, Anna Botsford Comstock of 18, and some 15 other persons wrote one or more leaflets. Leaflets continued for more than 50 years along with the dedicated personal services of very effective educator-

scientists. Two such persons who served for a number of years were Anna Botsford Comstock and E. Laurence Palmer. In the *Teachers Leaflet* for May 1897 Bailey gave his thoughts about the survival of nature study.

> Real nature-study cannot pass away. We are children of nature, and we have never appreciated the fact so much as we do now. But the more closely we come into touch with nature, the less do we proclaim the fact abroad. We may hear less about it, but that will be because we are living nearer to it and have ceased to feel the necessity of advertising it.
>
> Much that is called nature-study is only diluted and sugar-coated science. This will pass. Some of it is mere sentimentalism. This also will pass. With the changes, the term nature-study may fall into disuse; but the name matters little as long as we hold to the essence (6:13).

The condition of nature study and a major influence that was to effect its future was described by Ira Butron Meyer in 1910 as follows:

> Up to this date there had been no cooperative efforts on the part of advocates of nature study and little attempt to define, in any broad and comprehensive way, the fundamentals of nature study, to determine what it really is, its scope, and the character of the work which it should attempt to do. At this crisis in the situation, when people began to say that the work was in bad repute, when eminent educators contended that it was a dangerous fad, Prof. M. A. Bigelow came to its rescue in the founding of the Nature Study Review (34:246).

The *Nature Study Review* and the Nature Study Society, which was founded in 1908, did continue to promote nature study both in essence as well as a course title in the elementary schools. As a result nature study did maintain its prominence for many years. However the essence has not only continued at elementary school levels but also at secondary and collegiate levels. Youth movements such as the scouts and 4-H clubs took up the essence. This movement into informal education was reported in 1926 as follows:

> Much could be said concerning trends and tendencies in nature study and elementary science, but limitations of space necessitates elimination of all save developments which are distinctly new and prophetic. The increasing use of nature study in summer camp work, the growth of

the nature guiding movement which has become a feature of the National Park Service, the adoption of programs of nature study and elementary science in the work of the Playground and Recreation Association of America, and the cooperation of museums with school systems in carrying out well organized and conducted programs of nature and science education are matters of significance, which furnish suggestions to the forward-looking educator (36:61).

The development which hastened the trend toward disuse of the nature study title was a new direction in organizing a program for science at elementary school levels. Gerald S. Craig tried to find a basis for a structure in 1927 when he was faced with the need to develop a science course of study for the Horace Mann Elementary School. He studied the practices that were current at that time. He found that "the outstanding characteristic of the nature study and science programs in the elementary schools seemed to be a lack of organization (7; 9:41).

Craig studied the functions of an elementary school science program. He developed a list of objectives and arranged for the help of a corps of competent people to evaluate these objectives in terms of their importance. He studied the interests of children. He studied authoritative source books. From such information he developed key meanings that contributed to the objectives. Then he designed units with instructional aids for the teachers so that they would be able to help children understand the key meanings. Much of what he designed was excellent nature study but it was called elementary school science. The stress on "key meanings" was different and the use of such key meanings as the basis for organizing a science program produced a different plan. In the years that followed science programs became organized more commonly around key meanings. Materials with real phenomena were used in the development of the meanings. Natural objects became supportive. The essence of nature study was not lost but the use of nature study as the title for a science program at elementary school levels fell more and more into disuse.

THE GENERAL SCIENCE MOVEMENT: OUR FIFTH REVOLUTIONARY CHANGE

An urgency to develop a significant science program for the first two years of high school grew out of the limitations placed on teachers and school leaders by the series of steps taken between 1880 and 1900 to promote academically respectable science courses in the high schools. Many youths were not able to succeed in such courses. Furthermore a growing number of youth entered the high schools and often remained only a year or two. The problem of

providing a meaningful and useful science course was a very real one. There were few restrictions at the level of the entering years of high school so innovations were possible.

In September, 1904, a course "mildly physics and chemistry" was offered in Springfield, Massachusetts. "The following year some astronomy was added and little by little the other sciences found a place, until the course became in fact, as well as in name, a course in General Science.(28:135)." W. F. Roecker made a study of what had happened in the movement up to 1914 and wrote:

> At present the subject is spreading rapidly in this state and throughout the country. This is largely due to the satisfactory reports which have been received from the prominent centers in which the work has been given a trial. Springfield, Mass., Pittsburgh, Pa., Oak Park, Ill., Providence, R.I., Bridgeport, Conn., Illinois State Normal University at Normal, Ill., Wichita, Kan., Gary, Ind., and Madison, Wisc. may be mentioned as such centers. Most of these schools have developed some kind of a manual and organized their courses according to some specific type. Thus at Oak Park, physiology is made the unifying subject; in Bridgeport, mineralogy serves the same purpose. At Normal, Ill. physics is made the primary part of the subject while in Madison (city high school) elementary biology forms the core (50:756).

General science did not appear in the statistical summaries on offerings and enrollments from the Office of Education, United States Department of Interior, until the year 1922 when 18.27 percent of the students in high school were enrolled in this subject (26). The statement about the sciences in the 1934 report was as follows:

> The leader in the science group is general science both in number of offerings and in number of registrations. Moreover, it leads in the last 4 years of high schools as well as in seventh and eighth grade. Its ascendency over the other sciences is especially prominent in the seventh and eighth grades, where it has between six and seven times as many registrants as all the other sciences combined (26:14).

A committee on The Reorganization of Science in Secondary Schools was appointed by a commission of NEA in 1913 and a report appeared in 1920 (4). The committee related its report to the *Cardinal Principles of Secondary Education* which had appeared in 1918 (60). Of the seven main objectives stated in this 1918 report the committee considered the sciences to be especially

valuable to the realization of six cardinal principles. The committee made the following statement about general science:

> This introductory course in science is not a substitute for any one of the special sciences, but should provide a basis for discovery of interest in special sciences and of vocational opportunity. It should prove to be the best training for any pupils who can take only one course in science in high school (4:25).

The report went on to discuss the selection and organization of the course content which they stated should be to a large extent from the environment and useful in developing true interest. They discussed the methods to be employed and gave examples of topics with recommended content. As a result of this report and other endorsements the course in general science came to be accepted as a very important course among the sciences of the secondary school.

Edward E. Cureton made a study of general science in 1927. He set as his goal the determination of the basic aims of the course, the functions of the science laboratory, the best methods of teaching, and the topics and problems which should be considered as essential. He stated as his finding that "There is no general agreement concerning the basic aims of junior high school science (9:89)." He went on to indicate that the aims could be classified in such areas as appreciation, formal subject matter knowledge, and cultural values. The principal function of a science laboratory for general science was to provide illustrations of important facts and principles. Demonstrations by the teacher or in cooperation with students were prominent methods of teaching. Cureton found more than 200 topics in general science courses, 15 of which were most frequently included. Expert opinions supported the idea that intensive reading, recitation, and lecture were too commonly being used in the teaching.

Elwood D. Heiss reported his study of high school general science courses in 1932 (10:55). He found that he could group the course content under 12 topics although there were many additional topics. He found agreement on the point that the content should be organized from the point of view of the environment without any regard to the major divisions of science. He found wide variations in the degree to which students mastered the facts, principles, and applications. These variations were best explained on the basis of variations in intelligence of the students.

General science continued to be the leader in student enrollments among the high school sciences through 1934 and second only to biology in 1947 (27). In a period of 25 years general science developed a very secure place among the major science courses of the four- and the six-year high schools.

General science courses have changed over the nation and over the years. As a science course it has been relatively free from controls. It has therefore been adapted to meet the changing needs of youth.

FOUNDATION SUPPORT FOR CURRICULAR CHANGE: OUR SIXTH REVOLUTIONARY CHANGE

During World War I it became known that poisonous gas was likely to constitute an important munition. In preparation for such an eventuality the government called upon its ablest research chemists to provide a means for defense, to solve problems of production, and to provide our field forces with an ample supply of the new weapon. Results of the team approach were forthcoming with a speed and certainty that amazed national leaders. After the war was over The Chemical Foundation, Inc., became a means for an educational campaign to promote the study of chemistry. This campaign took several forms of which two became widely known to high school chemistry teachers.

One form was a distribution to high school chemistry teachers of very readable and interesting books related to chemistry. The hope was that the teachers would read them and encourage their students to do likewise. There were two books reporting on chemistry in industry (19, 20), one on chemistry in agriculture (5) and one on chemistry in medicine (55). There may have been a total of ten books. To the isolated chemistry teacher this was a greatly appreciated means to call attention to the valuable results that chemistry had brought to the lives of all our people. Certainly the teachers made use of the materials in their teaching.

Another form of help was the establishment in 1922 of The Division of Chemical Education of the American Chemical Society (ACS). This division established a committee to develop a standard minimum high school course in chemistry. The committee held its first meeting in 1923 and made a report in 1924 (18). The committee invited criticisms and suggestions from high school chemistry teachers and received about 30,000 suggestions within six months. Among the responses was one provided to high school and college chemistry teachers through the medium of their own journal. Among other comments, Charles H. Stone included the following:

> If the first and only function of the high school were to prepare its pupils for college, there could be little argument as to the content of its chemistry course. It would only be necessary to follow the outline for chemistry instruction as given in the Syllabus of the College Entrance Examination Board. No other course would need

to be considered. The principal argument which might be advanced against the present syllabus would be that it is much too comprehensive and cannot be covered satisfactorily in the usual one year high school, or preparatory school course, unless it be in some special school which devotes its attention exclusively to training a selected group of students for admission to college. . . . It seems to me that th time has come when the rights of the ninety per cent mu be more fully recognized. The time has come when it should be possible for teachers in all preparatory schools to give a course which shall not be so tied down to college requirements as to prevent instruction in the chemistry of the students environment (56:55,58).

The minimum standard list was revised and a list of supplementary work and additional topics included. Again this material was widely distributed so as to reach most of the high school chemistry teachers. Suggestions for further revisions continued to be received by the committee. Among other suggestions many teachers proposed two high school chemistry courses: one for general education and one for preparatory work looking toward college studies. The committee responded to this idea in a very definite manner.

The Committee does not feel that it is practical or necessary to have two different courses in high schools, that is, one course for those who expect to attend college and one for those who do not. . . . The Committee wishes to reiterate and to emphasize that it is not the purpose of the foregoing syllabi to "standardize" the teaching of chemistry. The Committee would consider any such result of its labors as a misfortune, indeed. If, however, a course in high school chemistry can be made to mean something definite which the colleges may take for granted in the same way that they do high school English and mathematics, for instance, and if unnecessary duplication of effort can be eliminated to an appreciable extent much will have been accomplished (17:656).

Much was accomplished through the extensive involvement of the high school chemistry teachers and the dedicated efforts of leaders among chemists. Both of these became possible through the foundation support. It is appropriate to note what R. W. Edmiston reported in 1931:

During a study of overlapping in secondary school sciences, objective tests pointed out the more thorough scientific preparation of the chemistry group than that of either the biology or physics group. Since the test groups were similar, the divergence called for further.

consideration. The lesser and more unified content of the teaching efficiency, or pupil interest or both which has resulted from The Chemical Foundation through the American Chemical Society are the two differences discovered that can account for the more thorough scientific knowledge of the high school chemistry group (12:556).

The work of the committee continued over about 15 years and several additional reports were developed to meet needs suggested by the high school teachers. The overall favorable results, due in part at least to the extensive involvement of active high school chemistry teachers made possible by the necessary financial support, influenced the chemistry instruction for many years. While physics enrollments had exceeded those of chemistry from 1890, chemistry enrollments became the leader in the physical sciences in the 1928 report and chemistry enrollments extend[illegible] he margins in 1934 and in 1947 (27).

TOWARD PRINCIPLES AND MAJOR GENERALIZATIONS: OUR SEVENTH REVOLUTIONARY CHANGE

The biological sciences consisted of separate courses in botany, physiology, and zoology into the twentieth century. The condition in 1913 was reported by a committee in Kansas.

> After due consideration and extensive correspondence with the high school teachers of the biological sciences in the state and in fifty representative cities of the country in general, a majority of the committee has become convinced that a general course in biology, rather than separate courses in botany and zoology as such, should be given in the second year of the four-year high school course as at present generally organized.
>
> What the majority of our committee favor is a course that has not yet appeared, but which we believe can and will be developed (49:146).

The committee that prepared suggestions and recommendations for the report on *The Reorganization of Science in Secondary Schools* in 1920 stated very clearly what they had in mind for the biological sciences.

> The Committee believes that a course in biology in the ninth and tenth grades should be what the name implies . . .a study of living things (4:31).

An approach to a unified biological science course based on fundamental biological principles was very slow in developing as revealed by Alfred Kinsey in 1930.

An examination of current textbooks and state syllabi similarly show that we are undecided whether our introductory course should involve a one-half year of botany followed by a one-half year of zoology, or a unit synthetic concerned with generalizations applicable to all organisms (29:374).

Even in 1932 Wilbur L. Beauchamp reported that 89 percent of the biology courses of study he examined were divided into three major divisions: one devoted to plants, one focused on animals, and another directed to the study of man (1). The remaining 11 percent were organized around fundamental life processes and activities.

The rate of change increased rapidly following the publication in 1932 of the NSSE Thirty-First Yearbook, Part I (4). This study bore the title *A Program for Teaching Science*. The summary statement developed by the committee as it concerned biology was:

> This Committee supports the thesis that the materials of biology courses should be organized definitely in such a way as to contribute to an understanding of biological principles, to the end that this training may contribute to a reification of major generalizations and their accompanying scientific attitudes (41:239).

While the area of biology has been used as an example of the movement toward a science course organization based on principles and big ideas, the Thirty-First Yearbook committee made it clear that their recommendation applied to all leaders in all areas and at all levels of science instruction. They stated that major generalizations and the associated scientific attitudes were to be seen as of such importance that an understanding of them is made the objective of science instruction. This resulted in much curricular work involving attempts to identify the major generalizations, principles, theories, and other big ideas. After identification there was a need for their proper formulation. This was often followed by a determination of their importance for general education. Attempts were then made to develop activities through which an understanding of the ideas would develop in the minds of the students.

The organization of a course in physical science began to develop in the minds of several leaders when the biological sciences were being generalized around major principles. Physical science courses began to appear here and there in 1934 to 1940 (35).

There was also increased attention given to major principles within the existing courses. The movement toward an organization based on principles was a pervasive one and it influenced the thinking of leaders in science education who were concerned about elementary, secondary, and collegiate science instruction. It was pervasive also in that it gained widespread acceptance and continued to influence the development of science courses from the time of its introduction.

THE HUMAN NEEDS EMPHASIS: OUR EIGHTH REVOLUTIONARY CHANGE

During the decade of the Great Depression from about 1930 to 1940 there was a great influx of high school age youth into the schools. There were limited opportunities for work and the schools were accepted as a constructive haven for all youth. It also developed that some of the youths could be more appropriately served in the Civilian Conservation Corps (CCC) and the National Youth Administration (NYA). By 1940 28 states reported that 90 percent of the 14- and 15-year-old youths were in school. For many of the youths the high school experience would amount to a year or two or at the most graduation. But many students in the same schools expected to graduate and to be admitted into the college of their choice. This condition made it necessary to find appropriate curricular adjustments.

The revolutionary change in education from major attention to specific information to concern for fundamental principles and significant generalizations was in itself a recognition of human needs. Teachers had noted again and again that students forgot very rapidly what they had learned, especially the specific information peculiar to their course. The roots of the change were much deeper.

The leaders in science education organized in 1928 The National Association for Research in Science Teaching (NARST). They had arrived at the conclusion that real progress in science teaching must rest upon facts obtained through research. One of the leaders, Francis D. Curtis, developed a means for the dissemination of the results from research efforts. His *Investigations in the Teaching of Science* were studied widely (9, 10). The association often met in conjunction with the American Association of School Administrators (AASA) and the results of investigations were readily communicated to school leaders. Furthermore the committee for the Thirty-First Yearbook (41) included many of the research-minded leaders in science education. The problems occasioned by the large influx of students into the high school could be faced by curricular and instructional innovations based on science education research.

It is impossible in this chapter to call attention to many investigations that contributed to changes in direction that helped the schools to respond to individual and societal needs. Ralph Tyler reported in 1930 that students retention of specific information was much less than their retention and ability to explain everyday phenomena and to apply facts and principles (10:305). Other investigations added findings of the same nature. Teachers also had learned that everyday phenomena and applications seemed to be of substantial interest to youth, especially those who did not plan to go to college. Surely greater stress on applications of principles and explanations of phenomena was a way to recognize individual, societal, and teacher needs. In the revision of science courses the direction was toward making them more general, more applied, more suitable to the wide spectrum of interests and abilities found among the students.

The change of biology from separate divisions or even separate courses on botany, physiology, and zoology to general biology courses was a way to recognize needs. The demand to recognize individual and societal needs was especially acute in the biology area because of the many youths in school at the 10th grade level that elected to take biology as their science since biology also met the requirement of a laboratory science for graduation. Not only did a variety of general biology courses emerge but also such courses as biology and human welfare, conservation, life science, health science, civic biology, and the like. Many high school and college biology teachers were very unhappy with this trend. They felt a need for an organization where they could exchange ideas about what was happening. The National Association of Biology Teachers (NABT) was organized in 1938 and *The Biology Teacher* became their journal.

The Union of American Biological Societies established a Committee on the Teaching of Biology in 1939 and mailed 16,000 copies of an elaborate questionnaire to biology teachers throughout the United States. They were concerned about the teaching of biology in the schools. A finding such as the following did not give them much comfort:

> Substitution of a social study for a biological study--a movement led by large cities and doubtless still in progress--has lately occurred in about 10% of our schools. Approximately 9.8% of the replies indicate that a biological subject--hygiene in 61% of cases--has been transferred to the teacher in physical education during the past 5 or 10 years (48:76).

They found decreased time for laboratory work to the point where five periods per week was the common amount of time for both class and laboratory work. Then they gave the following conclusion:

> The high school teacher of biology cannot alone resolve the many questions relating to his own adequate training, to his opportunity to teach an adequate amount of biology, and his freedom to teach the foremost principles of his science (48:76).

Not only were the leaders among the biologists stirred into action but also the leaders among the physical sciences who were faced with a movement toward the generalization of physics, chemistry, and other physical and earth sciences into some type of fused or physical science. There were under way such modifications of chemistry and physics as applied chemistry, dynamic physics, advanced general science, and fused chemistry and physics. The leaders who were concerned about the academic respectability of their area formed the American Association of Physics Teachers (AAPT) in 1930 and the American Science Teachers Association (forerunner of NSTA) in 1934.

One further development that sharpened the focus of many who were bothered by the individual and societal needs emphasis was the establishment in 1938 of the Committee on the Function of Science in General Education. This committee was an outgrowth of the Commission on Secondary School Curriculum of the Progressive Education Association (PEA). In their report on science they gave a brief review of developments in science teaching. They included the following statement:

> This brief survey of present trends in science teaching reveals that there is probably less agreement as to the purposes of science instruction at the present time than there was in previous periods. This increasing confusion is due in part to the fact, earlier noted, that purposes and programs that were reasonably successful in a given period have been carried along and still permeate practice, even though conditions that gave them validity have now changed (57:15).

In their report the committee revealed that their curriculum planning and experimentation would be needs oriented rather than science oriented. Needs were classified in such areas as personal living, personal-social relationships, social-civic relationships, and economic relationships. An illustration of the types of science courses they had in mind was functional chemistry which gave considerable attention to drugs, medicines, internal secretions, bacteria and disease, clothing, cosmetics, and hobbies. Another example was fused physical science with attention to household machines and appliances, public utilities, industries, matter and energy. Other illustrations were public health and genetics.

The Department of Science Instruction of NEA increased its activities during the confusion of the depression years. The department began to publish yearbooks in 1935. These publications included the papers presented at their convention and usually bore the title of the convention theme. In 1937 the department sought special grants from NEA for the purpose of organizing a national committee on science teaching. A grant of $1,000 was received; the existing organizations of science teachers were invited to participate by naming a member or at least a consultant. Nine organizations accepted, a meeting was announced, subcommittees were established, additional small grants were received, reports were developed and published (8, 42).

The work on these reports gave science teachers and science education leaders opportunities to exchange many ideas. Many of them accepted the philosophy that individual and societal needs must come first in the organization of science courses and in planning instructional practices. For them the decrease in or total dropping of time for laboratory work produced no trauma. Even the increasing use of instructional films showing the use of science in everyday affairs and in scientific pursuits during laboratory and classroom periods seemed to be a good thing because the students displayed considerable interest in the films; research findings such as those of Philip J. Rulon showed that there could be real gains in retained achievement by the use of selected films (10:336). But there was another group of science teachers and science educators who deplored the "watering down" of science courses. They lamented the decreases in time for laboratory work. They felt strongly that something must be done to strengthen the science part of science instruction. The various scientific societies and associations were the allies of these science-minded individuals.

Many very difficult problems had to be faced by science teachers and school leaders during the depression years. Individual and societal needs were indeed great and great adjustments were made in attempts to recognize them. In addition to revising existing science courses and developing new types of courses there were also many adjustments in instructional practices such as ability grouping, individualized instructing, and small group instruction. The academic respectability of many science courses was compromised in many cases. It is impossible to find in the publications of the 1940 to 1941 period any clear lines to a proper balancing of the needs emphasis with the science respectability point of view. The issue never came to a confrontation because World War II began and science teachers, scientists, and school leaders joined together to win the war and secure the peace.

The recognition of a war emergency was in itself an attempt to recognize individual and societal needs. The need became to prepare youth for effective performance during the emergency. This

meant the development and offering of new science-based courses that would help youths make rapid and effective progress during basic training and then to perform well in the offensive, defensive, and productive units of the nation. So far as new courses were concerned it meant the adoption of pre-induction training outlines such as fundamentals of machines, fundamentals of shopwork, fundamentals of electricity, basic electronics, and other courses related to aviation, called preflight aeronautics. Some of these special courses were developed by the Pre-Induction Training Section of the War Department in cooperation with the U. S. Office of Education (USOE). Military and educational leaders urged the schools to make such courses available. John W. Studebaker, the U. S. commissioner of education, closed his message to school leaders with the following words:

> Mastery of these course materials on a pre-induction basis by thousands of youth will enable the Army to cut the post-induction training time necessary to insure the superior competence of our men in modern mechanized warfare. The courses may thus help to preserve the lives of thousands of soldiers. Let it never be said that any soldier's life was ever forfeited because we failed to do our part to provide him with adequate training (47:iv).

Not only were many needs-oriented science courses abandoned and others greatly deemphasized but also projects that were designed to promote the needs types of courses were greatly slowed down or terminated because critically important personnel became involved in the war effort. Some new needs in addition to those directly related to military effectiveness came into the schools such as physical fitness, health, war gardening, and fuel economy. The needs emphasis was redirected and related to the military emergency. It did not disappear from the educational scene. The designing of science courses with individual and societal needs in mind came into the schools during a depression emergency and it was greatly modified during a military emergency. Much of the needs emphasis was found when the war was over but new needs appeared and further modifications were required. Our schools as social institutions will undoubtedly continue to be sensitive to contemporary needs.

THE NURTURE OF FUTURE SCIENTISTS: OUR NINTH REVOLUTIONARY CHANGE

The scientific and technological nature of World War II caused a severe relocation of many high school and college science teachers. Many graduate students in the sciences and mathematics also entered military service or became involved in research and development related to the war effort. Then too a very large number of

science-talented youth postponed their entry into collegiate studies in order to serve their nation during the emergency. War necessities stopped or severely limited the production of consumer goods. Many new developments were concomitant products of the war effort and many of them offered possibilities for peacetime uses. The needs for a successful culmination of the war and for the years that would follow were expressed by M. H. Trytten in 1945.

> The present supply of technically trained persons will apparently be so busy keeping up the status quo that the necessary tempo of new developments may not be possible.
>
> These considerations should mean to science teachers a special awareness of the need for the highest devotion to the teaching of sound, solid work in the sciences at the beginning levels. We need an enhanced flow of capable men into the advanced levels of scientific and engineering instruction. It is in the interests of the nation as a whole that a flow of capable, sincere students in the sciences return as soon as possible to the regular training courses in the universities and the graduate schools (58:47).

This was not only a concern of scientists and engineers. It permeated the thinking of many leaders outside of the scientific community. As an example the Advisory Committee, Intermission Science Series, New York Philharmonic Symphony Broadcasts, put their thinking in the following form:

> As it became clear that World War II was drawing to a close, those in charge of the Philharmonic Broadcasts felt that the time had come when it was less important to stress historic values, as had previously been the aim of the intermission program, and more important to look forward into the future.
>
> What the future would be, no one could forecast. But one thing was sure; science would be a mighty and pervasive force in helping to shape that future (62:v).

The result of their decision was a prolonged series of weekly talks by scientists and engineers about their special interests and pursuits. Through the active encouragement of science education leaders the first series of talks was bound into booklet form and the second year resulted in a book (62). Both of these series of talks were distributed free to many high school science teachers with opportunities to order additional copies at a modest cost.

Arthur H. Compton, a Nobel Prize winner in physics and a leader among educational administrators as well, expressed the motivation of the scientific community for participating in and endorsing this project:

What I want especially to stress is the fact that greatly increased emphasis on science is a "must" for our nation's safety and future welfare. If a wise course is followed with regard to recruitment, training, and in other support of science, our nation is in a favorable position to lead the world in the scientific age that lies ahead (62:337).

During the period of the war there were opportunities only for science education leaders to meet either in a greatly reduced type of convention or in the production of materials for use in the schools as a part of pre-induction training. The tensions resulting from the emphasis on individual and societal needs while scientists deplored the weakening of science courses were well known to them. In their own minds both the scientific nature of the courses and adaptations to needs of all students, including science talented students, must go hand in hand. The American Council of Science Teachers, then the Department of Science Instruction of NEA, and the American Science Teachers Association, the affiliate of the AAAS, merged into the National Science Teachers Association (NSTA). In the future the conventions, the journal, the special publications, and the other activities were to give emphasis both to solid science and to the best in instructional practices (40).

Early in 1946 this new NSTA was asked by the United States Department of State to develop a report on science teaching in the United States. This was to serve as an aid to nations of the world in their rehabilitation of science and mathematics. The Cooperative Committee on Science and Mathematics Instruction of AAAS with representatives from the major scientific and mathematical societies gave major assistance to this project. The report gave outlines of science and mathematics courses, it described school facilities, it listed the supplies and equipment, and it discussed instructional practices. The report included the elementary school level, the secondary school years, and the undergraduate college offerings. The following statement appears in the introductory part of the report:

In practice, the preparation of specialists has had the first claim on the attention of teachers. Science instruction "for all" has been less well done, in spite of the American ideal of "education for all." The contributions of science to the thought pattern of the citizen has been enormously accelerated by the war. There is, therefore, a need for increased emphasis on science education for all (46:7).

Several thousand copies of the report of 186 pages were distributed abroad in 1947 through the cooperation of the Preparatory Commission of the United Nations Educational, Scientific, and Cultural Organization (UNESCO).

Vannevar Bush, director of the Office of Scientific Research and Development, had been requested by President Roosevelt to develop a report with recommendations for strengthening the overall scientific enterprise of the nation. He reported in 1945 and among the recommendations were the following:

> It is my judgment that the national interest in scientific research and scientific education can best be promoted by the creation of a National Research Foundation (3:28).

> The Foundation here proposed has been described only in outline. The excellent reports of the committees which studied these matters are attached as appendices. They will be of aid in furnishing detailed suggestions.
> Legislation is necessary. It should be drafted with great care. Early action is imperative, however, if this nation is to meet the challenge of science and fully utilize the potentialities of science. On the wisdom with which we bring science to bear against the problems of the coming years depends in large measure our future as a nation (3:34).

This report and the appendices developed by special committees were studied. They formed the bases for further recommendations. Of special significance were the recommendations developed under John R. Steelman, chairman of the President's Scientific Research Board in 1946. Five volumes were devoted to a discussion of various facets of the scientific personnel problem. Volume One bearing the title *A Program for the Nation* stated their key recommendation as follows:

> It is, therefore, recommended that the Congress be urged to establish at its next session a National Science Foundation within the Executive Office of the President and that the Foundation be authorized to spend $50 million in support of basic research its first year, with increasing amounts thereafter rising to an annual rate of at least $250 million by 1957. No restrictions should be placed upon the fields of inquiry eligible for support (54:31).

Also in this report we find the following statement which was of special significance to high school science teachers:

> Our scientific strength depends neither solely upon our present supply of scientists, nor upon those students now being trained. It depends ultimately upon a steady flow of able students into our colleges and universities (54:35).

Volume Four was devoted to personnel for research. The causes of the severe shortage of scientists and engineers were given. The need for additional personnel was presented by statistical tables, graphs, and statements. Appendix II to this report was developed by the Cooperative Committee on the Teaching of Science and Mathematics. The major organizations of science teachers were represented on this committee and participated in the development of the material. It encompassed the elementary, secondary, and collegiate levels and treated both the sciences and mathematics; it provided an appraisal and a series of recommendations. It was an important opportunity and a great challenge for the committee.

> The dual responsibility of insuring that we have (1) enough competent scientists to do whatever job may be ahead and (2) a voting public that understands and supports the scientists' role in defense and in the design for better living, rest heavily upon the Nation and all men of science in these fateful days.
>
> To this committee has been assigned the sobering task of making recommendations looking toward the creation of a corps of effective research scientists and of discerning science educators. The crucial task of the education of the general public in the nature and function of science in the world of tomorrow looms in the background throughout this study, though it appears overtly at only a few points (53:57).

The recommendations were arranged under immediate action and long range solutions. Immediate action proposals included federal subsistence scholarships for the scientifically gifted, postgraduate fellowships, and in-service training workshops for teachers. Included in the major recommendation was the provision of science and mathematics supervisors throughout the nation. Long range recommendations included curriculum revision, help to identify the talented, the provision of improved guidance procedures, and a clearinghouse for information on research facilities and research staff for help in the guidance and placement of the talented students.

The appendix went on to indicate the weaknesses of science and mathematics instruction at all levels. These included the proper and effective sequencing of the instruction, the inadequate placement of concepts, the limited opportunity to study the physical sciences, the lack of interest among students in seeking careers based on science and mathematics, a lack of identification and encouragement of the talented, and the serious needs for an expansion of instructional facilities and staff. Special attention was directed at the need for improved preservice and in-service preparation of teachers.

There was no general agreement on what would be the best way to provide a suitable education for those who would go on and seek careers in science and mathematics. Attention to individual and societal needs so prominent during the depression years were still common at high school levels and were attracting staff at college levels. The case was made for generalized science courses such as general biology and general physical science or even broader integrations crossing subject matter lines and producing a core curriculum. Powers and Fitzpatrick had a chapter on secondary school science in a publication devoted to generalized science courses at the college level. They stated the key question as follows:

> At first thought, it might be concluded that the recommendations of general education and the need for scientific manpower are hopelessly opposed, yet in practice such is not necessarily the case. Actually, many leaders of scientific thought and action assert that the successful specialist must have a broad understanding of modern culture, including the interrelationships of the various sciences, upon which to rear the superstructure of his speciality, and it is insisted that progress in science will be advanced as the general public gains in understanding of science and its potentialities. So we return again to the key question as to when specialization should begin, and its corrollary which concerns whether or not this should be at the same maturity level in the case of all individuals who can hope to carry on advanced studies with profit (31:368).

Other leaders in science and in science education saw a need for a broad foundation but they also saw the need for specialization.

> But specialization must be built on a broad foundation. The implications for the education of potential leaders in the sciences and their application are clear; their study of mathematics and the basic sciences must be extensive; and it must start early, for they will need their later college and post-college years for professional training and other kinds of specialized work (44:8).

One critical problem in many high schools was the fact that the needs must be recognized in the one school and often in the same class. Certainly individual and societal needs could not be ignored. There must also be appropriate attention given to the students who had the potential to become the productive scientists and engineers of the future. This was the general condition and the dilemma as we approached the 1950 mid-century.

IN CONCLUSION

This chapter has presented some major changes in science education during the 1850 to 1950 period. Many other changes were considered for major attention. One characteristic of a major change was its persistence after its introduction. Here the individualization of instruction was eliminated because it did not seem to capture the imagination of science teachers or school leaders although it was used during the depression years as a way to accommodate varying interests and abilities. Unit organization and mastery plans were eliminated for the same general reason. It is expected that other authors will see other major changes. The real test of the significance of a change will be to identify something in our schools akin to it.

Whether the change was a desirable one or not was not at issue. It would have been almost impossible to determine such a factor. The author contends that we do see object study in our schools and we note it also as nature study, laboratory work, field work, and projects. Certainly science teachers are sensitive to the opinions of their college colleagues and they seek their counsel. General science and general biology are found in our schools and they represent important parts of the science program. Foundations have from time to time played an important role in the improvement of science instruction. The science courses are often organized around important science concepts and science teachers plan to inculcate these meanings into their students. Schools and science teachers are concerned about the needs of students and the needs of society. What science teacher does not take special pride in the success of a student he or she taught and encouraged to seek a career based on the sciences. Are these influences desirable? The kinds of people we have beyond 1950 and the nature of our American democracy in the years ahead will provide the evidence.

REFERENCES

1. Beauchamp, Wilbur L. *Instruction in Science*. U. S. Office of Education, Bulletin, No. 17, 1932. National Survey of Secondary Education, Monograph No. 22. Washington: Government Printing Office, 1933.

2. Boyden, Arthur C. *Nature Study by Months*. Boston, New York: New England Publishing Company, 1898.

3. Bush, Vannevar. *Science The Endless Frontier*. A Report to the President. Washington: Government Printing Office, 1945.

4. Caldwell, Otis W. (chairman). *Reorganization of Science in Secondary Schools*. U. S. Bureau of Education, Department of Interior, Bulletin No. 26. Washington: Government Printing Office, 1920.

5. Chamberlain, Joseph S. (ed.). *Chemistry in Agriculture*. New York: The Chemical Foundation, Inc., 1926.

6. *Cornell Nature-Study Leaflets*: New York State Department of Agriculture [illegible] re-Study Bulletin No. 1. Albany: J. B. Lyons Company, Prin[illegible] 1904.

7. Craig, Gerald S. *Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School*. Contributions to Education, No. 276. New York: Bureau of Publications, Teachers College, Columbia University, 1927.

8. Croxton, W. C. (chairman). *Redirecting Science Teaching in the Light of Personal-Social Needs*. Washington: American Council of Science Teachers, 1942.

9. Curtis, Francis D. *Second Digest of Investigations in the Teaching of Science*. Philadelphia: P. Blakiston's Sons & Co., Inc., 1931; New York: Teachers College Press, 1971.

10. Curtis, Francis D. *Third Digest of Investigations in the Teaching of Science*. Philadelphia: P. Blakiston's Sons & Co., Inc., 1939.

11. Downing, E. R. *Teaching Science in the Schools*. Chicago: University of Chicago Press, 1925.

12. Edmiston, R. W. "The Relative High Ability of the Chemistry Group in Comparison with the Biology and Physics Groups in Secondary Schools." *Journal Chemical Education* 8(1931): 556-558.

13. Fay, Paul J. "The History of Chemistry Teaching in American High Schools." *Journal Chemical Education* 8(1931):1533-1562.

14. Guttenberg, Gustave. *Science Teaching in Primary and Grammar Grades*. Report of the Elementary Department. Washington: National Education Association, 1890.

15. Harris, William T. *Syllabus of Lessons in Natural Science*. Seventeenth Annual Report of the Board of Directors. St. Louis: St. Louis Public Schools, 1871.

16. Hollis, Andrew P. *The Oswego Movement.* Boston: D. C. Heath, 1898.

17. Hopkins, B. S. (chairman). "Correlation of High School and College Chemistry." *Journal Chemical Education* 4(1927): 640-656.

18. Hopkins, B. S. "A National Standard Minimum Course in Chemistry." *School Science and Mathematics* 24(1924):233-237.

19. Howe, H. E. (ed.). *Chemistry in Industry.* New York: The Chemical Foundation, Inc., 1924.

20. Howe, H. E. (ed.). *Chemistry in Industry, Part II.* New York: The Chemical Foundation, Inc., 1924.

21. Jackman, W S. *Nature Study.* National Society for the Scientific Study of Education. Third Yearbook, Part II. Chicago: University of Chicago Press, 1904.

22. Jackman, W. S. *Nature Study for the Common Schools.* New York: Henry Holt, 1894.

23. Jackman, W. S. *Nature Study for the Grammar Grades.* New York: Macmillan, 1901.

24. Jackman, W. S. "Outline of a Course of Study in Nature Study, Geography and History in the Elementary Schools." *Nature Study Review* 1(1905):183-198.

25. Jackman, W. S. *Outlines in Elementary Science.* New York: Henry Holt, 1891.

26. Jessen, Carl A. *Offerings and Registrations in High School Subjects, 1933-34.* U. S. Office of Education, Department of Interior, Bulletin No. 6. Washington: Government Printing Office, 1938.

27. Johnson, Philip G. *The Teaching of Science in Public Secondary Schools.* U. S. Office of Education, Federal Security Agency, Bulletin No. 9. Washington: Government Printing Office, 1950.

28. Kelley, Howard C. "The Springfield Plan." *General Science Quarterly* 1(1916):191-200.

29. Kinsey, Alfred. "The Content of the Biology Course." *School Science and Mathematics* 30(1930):374-384.

30. Lloyd, Francis E., and Bigelow, Maurice A. *The Teaching of Biology in Secondary School.* New York: Longmans, Green, and Co., 1904.

31. McGrath, Earl J. (ed.). *Science in General Education.* Dubuque, Iowa: Wm. C. Brown, 1948.

32. Mann, C. R. *The Teaching of Elementary Physics.* In tract form. Chicago: Scott, Foresman, 1906.

33. Mann, C. R. *The Teaching of Physics.* Macmillan, 1915.

34. Meyer, Ira Butron. "The Evolution of Aim and Method in the Teaching of Nature Study in the Common Schools of the United States." *Elementary School Journal* 11(1910):205-213, 237-248.

35. Miles, Vaden W. *Principles and Experiments for Courses of Integrated Physical Science.* Ann Arbor: Edwards Brothers, 1950.

36. National Education Association. *The Nation at Work on the Public School Curriculum.* Fourth Yearbook. Washington: NEA, 1926.

37. National Education Association. *Report of the Committee on College Entrance Requirements.* Washington: NEA, 1899.

38. National Education Association. *Report of the Committee on Physics Teaching.* Washington: NEA, 1887.

39. National Education Association. *Report of the Committee of Ten.* Washington: NEA, 1893.

40. National Science Teachers Association. *The Platform for Action: History and Governing Rules.* Washington: NSTA, 1944.

41. National Society for the Study of Education. *A Program for Teaching Science.* Thirty-First Yearbook, Part I. Chicago: University of Chicago Press, 1932.

42. Neal, Nathan A. (chairman). *Science Teaching for Better Living. A Philosophy or Point of View.* Washington: American Council of Science Teachers, 1942.

43. Nelson, George E. "History of Biological Sciences in Secondary Schools of the United States." *School Science and Mathematics* 28(1928):34-42, 131-134.

44. Norton, John K. (chairman). *Education of the Gifted.* The Educational Policies Commission. Washington: National Education Association, 1950.

45. Powers, S. Ralph (chairman). *The Education of the Science Teacher.* Report of the National Committee on Science Teaching. Washington: American Council of Science Teachers, 1942.

46. Powers, S. Ralph (chairman). *Science Course Content and Teaching Apparatus Used in Schools and Colleges of the United States.* New York: United States Scientific Export Association, Inc., 1947.

47. Pre-Induction Training Section. *Fundamentals of Machines, A Basic Course.* U. S. War Department and U. S. Office of Education. Washington: Government Printing Office, 1942.

48. Riddle, Oscar (ed.). *The Teaching of Biology in the Secondary Schools of the United States.* A Report of Results from a Questionnaire, Committee on the Teaching of Biology. Columbus, Ohio: Union of American Biological Societies, 1942.

49. Roberts, Herbert F. "Biology in the High Schools." *School Science and Mathematics* 13(1913):146-152.

50. Roecker, W. F. "An Elementary Course in General Science: Content and Method." *School Science and Mathematics* 14(1914): 755-769.

51. Sheldon, E. A. *Lessons on Objects.* New York: American Book Company, 1863.

52. Smith, Alexander, and Hall, Edwin R. *The Teaching of Chemistry and Physics in the Secondary School.* New York: Longmans, Green, and Co., 1908.

53. Steelman, John R. (chairman). *Manpower for Research.* Vol. 4, Sc nce and Public Policy. Washington: Government Printing Oi...e, 1947.

54. Steelman, John R. (chairman). *A Program for the Nation.* Vol. 1, Science and Pub c Policy. Washington: Government Printing Office, 1947.

55. Stieflitz, Julius (ed.). *Chemistry in Medicine.* New York: The Chemical Foundation, Inc., 1928.

56. Stone, Charles H. "The High School Course Versus the College Entrance Requirement." *Journal of Chemical Education* 1(1924): 55-558.

57. Thayer, V. T. (chairman). *Science in General Education.* Report of the Committee on the Function of Science in General Education. Progressive Education Association. New York: D. Appleton-Century, 1938.

58. Trytten, M. H. "The Impending Scarcity of Scientific Personnel." *The Scientific Monthly* 60(1945):37-47.

59. U. S. Bureau of Education. *Bulletin 1882.* Department of Interior. Washington: Government Printing Office, 1882.

60. U. S. Bureau of Education. *Cardinal Principles of Secondary Education.* Department of Interior, Bulletin No. 35. Washington: Government Printing Office, 1918.

61. Wead, Charles K. *Aims and Methods of the Teaching of Physics.* U. S. Bureau of Education, Bulletin No. 7. Washington: Government Printing Office, 1884.

62. Weaver, Warren (ed.). *The Scientists Speak.* New York: Boni & Gaer, 1947.

63. Wesley, Edgar B. *NEA: The First Hundred Years.* New York: Harper & Brothers, 1957.

Addison E. Lee was born in 1914 in Texas. All of his formal education has been in Texas schools. After graduation from high school he attended Stephen F. Austin State Teachers College from which he was awarded his B.S. in 1934. His M.S. was awarded from Texas A & M University in 1937 and his Ph.D. was awarded in 1949 from the University of Texas at Austin.

Dr. Lee taught secondary school biology from 1934 until 1946 when he joined the University of Texas biological science faculty as an instructor of botany. He also taught biology and carried out research in plant morphology. He served in this capacity until 1959, rising to the rank of Associate Professor when he was appointed Professor of Science Education and Director of the Science Education Center. In 1965 he was appointed joint Professor of Science Education and Biology, the rank which he currently holds.

Dr. Lee has been active in NSTA, NABT, AAAS, AIBS, AETS, NARST, and the Texas Academy of Science. He was elected a fellow of AAAS and served as president of the Texas Academy of Science in 1962, president of NSTA in 1967, and president of NABT in 1973.

In addition to his regular teaching and administrative duties, Dr. Lee has served as Chairman of the Board of Directors and on the Executive Committee of BSCS. He has been a field coordinator of the NSF Chautauqua Courses held at the University of Texas at Austin since 1971. Between 1959 and 1973, Dr. Lee directed numerous NSF summer and AYI institutes for teachers. He has served as a consultant to ETS, Educational Research Council of America, and the Cooperative Science Education Center at Oak Ridge. He has also served as a consultant or participant in international conferences in England, Japan, Korea, the Philippines, Hong Kong, Malaysia, Thailand, Isreel, South Africa, and Brazil.

Dr. Lee has authored more than 100 publications including research papers, non-technical articles, and books. These publications have appeared in numerous education and science journals.

Dr. Lee's professional service to science education has been widely recognized. He was elected an Honorary Life Fellow of the Texas Academy of Science in 1963 and in 1975 the NSTA presented him with the Robert H. Carleton Award for national leadership in the field of science education.

A LOOK AT THE FIELD OF SCIENCE EDUCATION

ADDISON E. LEE

Professor of Science Education and Biology
Director, Science Education Center
The University of Texas at Austin

INTRODUCTION

The century in which we live has been given a lot of names--The Scientific Age, The Atomic Age, The Space Age, and many others. Regardless of the name, science is a common element. It logically follows that the "science education" of students in elementary and secondary schools has also been given much attention. The questions naturally arise "What have we done about science education?" and "what should we do about it?" During the first three-quarters of this century a great deal happened in science and in education that has influenced science education. During the first half of the current century more than a hundred committees looked at what was happening in the teaching of science and made recommendations (9). However, relatively little progress was made until after the first half of the century. During the 1950s progress in science education and in science was dramatically called to our attention by the advent of the Russian sputnik. During this period a great many scientists and science teachers turned their attention to the problems of science teaching.

In the mid-50s science teacher institutes were organized in many institutions of higher education for the expressed purpose of improving science teaching. Most of these were supported by the National Science Foundation (NSF). The effectiveness of some of these institute programs has been documented in a number of reports (14, 21, 23). These programs continued through the 50s and 60s into the early 70s. While the institute programs were focusing on science teacher preparation, parallel attention largely during the 60s was given to the development of new curriculum materials for teaching science. The development of both institute and curriculum materials was achieved through the cooperative efforts of scientists, science teachers, and other specialists in education. The curriculum development pattern included writing, tryout, and evaluation.

Toward the end of the 60s and beginning 70s support for science teacher preparation and the development of new curriculum materials and the implementation of these materials waned considerably. There were a number of reasons for this lack of support but one unfortunate reason was the pressure put on the United States Congress by so-called Textbook Vigilantes* who wanted to impose their own views on science teachers as to what should and should not be taught. William V. Mayer provides an excellent documentation of this situation at this time (13).

During this period and extending into the 70s attempts were made to make science education relevant to the social issues of the day. These attempts met with varying degrees of success but obviously did not solve the social issues of the day. As a part of this situation, or at least parallel to it, there developed in this country a kind of antiscience or anti-intellectual feeling on the part of many people. All of these factors plus a relatively high rate of unemployment for individuals highly trained in science now has resulted in a loss of interest in the part of many young people who might otherwise pursue science as a career.

Teachers and other people characteristically jump on and off bandwagons. Recently many science educators have turned away from the nature and substance of science as it is involved directly in the teaching of science and have focused their attention on some of the more general aspects of education that often have had bandwagon appeal. These aspects have included preoccupation with the development of behavioral objectives, competency-based programs, individualized instructional techniques, interaction analysis, modular instruction, flexible scheduling, team teaching, teaching with TV and films, and others. All of these topics are important and many have and will go beyond a bandwagon appeal. However, before we turn too far away from science we should ask ourselves whether or not science plays the same role in our life today that it played 40 or 50 years ago. Note for example the "energy crisis" and the "world food crisis." We should ask ourselves what role we may expect science to play in our lives tomorrow.

During the end of the 60s and into the 70s we have seen scientists leave science to become science educators. Recently we have been seeing science educators leave science education to

---

*This term was used by Gerald Piel who gave the banquet address at the 1976 annual convention of the National Science Teachers Association. The title of Piel's address was "Congress shall make no laws . . . ." He cited numerous details of legislative attempts to influence or inhibit science teaching.

become general practitioners in education and we are seeing some of the scientists who came into science education going back fulltime to science. Likewise some science educators are moving into educational psychology. The situation is somewhat fluid and admittedly some people can work effectively in more than one area. On the other hand we do not need in science education those who really are pseudo-scientists or pseudo-psychologists. If we have a field of science education then we should have science educators and both the field and those who work in it should have unique enough characteristics to be defined and identified.

THE NATURE OF SCIENCE, EDUCATION, AND SCIENCE EDUCATION

Implicit within the preceding remarks has been the idea of a distinct "field" of science education. We have no trouble identifying the field of botany or the field of zoology although for a time there was some debate as to whether there existed a field of biology. Now the field of biology is accepted and fields of chemistry, physics, astronomy, and geology are well established. Fields such as biophysics, genetic engineering, forensic medicine, and demography are also now established but were not heard of a few decades ago.

Is there a field of science education or is it merely two words together? There are people who do not use the words *science education* but rather refer to *education in the sciences* which obviously means something quite different. Science is defined in one dictionary as "the observation, identification, description, experimental investigation, and theoretical explanation of natural phenomena" (15). Science is defined similarly in other dictionaries. James Conant in *Science and Common Sense* defined science as follows,

> Science is an interconnecting series of conceptual schemes that have developed as a result of experimentation and observation and are fruitful of further experimentation and observation.

Conant goes on to say,

> In this definition the emphasis is on the word "fruitful." Science is a speculative enterprise. The validity of a new idea and the significance of a new experimental finding are to be measured by the consequences--consequences in terms of other ideas and other experiments. Thus conceived, science is not a quest for certainty; it is rather a quest which is successful only to the degree that it is continuous (7).

American Heritage defines *education* as "the act or process of imparting knowledge or skill, systematic instruction, teaching; obtaining of knowledge or skills through such a process, schooling; the knowledge or skill obtained or developed by such a process, learning; a program of instruction of a specific kind or level" (15). After checking several dictionaries, I did not find a definition of *science education*. On the other hand, if there is a field of science education we should be able to define it. Therefore, with full awareness of the risk involved, I propose the following operational definition of science education:

> Science education is a field of endeavor concerned with the teaching of science. Its substantive nature includes knowledge of (a) fundamental principles of certain related specific disciplines in science, (b) patterns and methods of science curriculum development, (c) instructional techniques and procedures for science teaching, and (d) the psychology of learning. It emphasizes skills for specific teaching techniques and in a broader sense in human relations as well as the personal characteristics of the teachers in terms of an inquiring mind, an attitude of open-mindedness, and understanding of the scientific enterprise and the relationship of science and society.

It is admitted that this is a broad definition and somewhat all encompassing; however, it may serve as a basis for developing a more precise definition which can be more definitive.

If we accept science education as a field of endeavor concerned with the teaching of science then we should begin to look at the nature of the substantive components of the field. A look at science is obviously beyond the scope of this chapter but it should be said that science is the central core of science education. It is in fact, the reason for its being--otherwise surely there is no science education.

While the substance of specific science disciplines is beyond the scope of this discussion we should keep in mind here certain basic principles of science. In 1964 the National Science Teachers Association (NSTA) sponsored a conference of distinguished scientists to identify the basic principles of science. The result was a publication called *Theory Into Action*.

The principles or conceptual schemes identified were as follows:

I. All matter is composed of units called fundamental particles; under certain conditions these particles can be transformed into energy and vice versa.

II. Matter exists in the form of units which can be classified into hierarchies of organizational levels.

III. The behavior of matter in the universe can be described on a statistical basis.

IV. Units of matter interact. The bases of all ordinary interactions are electromagnetic, gravitational, and nuclear forces.

V. All interacting units of matter tend toward equilibrium states in which the energy content (enthalpy) is a minimum and the energy distribution (entropy) is most random. In the process of attaining equilibrium, energy transformations or matter transformations or matter-energy transformations occur. Nevertheless, the sum of energy and matter in the universe remains constant.

VI. One of the forms of energy is the motion of units of matter. Such motion is responsible for heat and temperature and for the states of matter: solid, liquid and gaseous.

VII. All matter exists in time and space and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and in various patterns (16).

This list was not accepted universally by all scientists. It was considered satisfactory as a basis for the physical sciences but inadequate for the biological sciences. Bentley Glass (8) among others reported his objections. In general I am in agreement with Glass. Neither I nor Glass disagree with the list so far as it goes and for the area it covers, but it is clearly incomplete. I was challenged to suggest additions to make a more complete list. In response, the following principles were suggested as possible additions.

VIII. Matter that forms a living organism, while not different in terms of the elements it contains from nonliving matter, has unique characteristics in terms of the organization of these elements that are more complete than nonliving matter. It is the unique nature of this organization that separates living from nonliving. A living organism is a highly organized aggregation of matter which within a limited environmental range can utilize relatively simple matter. The organism uses part of this matter in maintaining itself and reproducing its kind while the remainder supplies the energy necessary for all of these processes.

IX. As the organization of matter in living organisms becomes more complex, the interaction of matter within the organism and between the organism and its environment becomes more complex--thus requiring an understanding of both the physical and the biological components of the phenomena of nature. The organism is not only a highly organized aggregation of matter in itself but is also a highly organized segment of its environment and depends upon the environment for all that it requires to maintain life.

X. Organisms can survive and be active in only a limited range of the physical environment. If the environment changes, the organism must adapt to the change or cease living.

XI. The environment around an organism is both physical and biological. Living organisms are not independent of one another but influence one another's environment to a marked degree. The primary interrelationship among organisms are competition for energy from the environment and specific dependences of the organism upon others which in some cases may be mutual.

XII. The most advanced and complex activity of an organism within its environment constitutes behavior. Understanding the biological roots of behavior is one component of natural science. An extension of the study of behavior as a part of natural science brings it to the interface of the natural sciences, psychology, and the social sciences.

According to Joseph J. Schwab characteristics of new curriculum study materials in the 60s had their origin in the history of the American science textbook which he divides into three developmental phases relating to the state of science at the time, the goals of the high school student, and changes in the size and nature of the student population (19). A study by William E. Brownson and Schwab was quoted as showing that more than 50 percent of the authors of high school science textbooks available in 1915 were in the roster of *American Men of Science* while in 1955 less than 10 percent of the authors were in the roster (6). The third phase of textbook development involved the cooperation of scientists, teachers, and other educators. In other words the textbooks represented the work of groups of authors rather than a single author. There were many advantageous results of this situation. One was that the Textbook Vigilantes had less influence on groups than they often had on on commercial publishers. The pattern and results of curriculum development that emerged during the 60s has been very successful.

The influence or impact of this development on subsequent science teaching and textbook preparation has been obvious in the field of science education as well as in other areas.

The textbook has always been central to curriculum development. It also influences teaching strategies. Any extensive discussion of this topic is obviously a textbook for science education instruction in a science teacher education program. A number of such textbooks are available and are useful to the science teacher and the science educator. Let us now look briefly at some teaching strategies that have been developed and used in science education.

Ernest Nagel, one of the participants of the 1964 NSTA Conference, prepared a list of major items in the process of science which was published in *Theory Into Action* (16). His list is as follows:

I. Science proceeds on the assumption, based on centuries of experience, that the universe is not capricious.
II. Scientific knowledge is based on observations of samples of matter that are accessible to public investigation in contrast to purely private inspection.
III. Science proceeds in a piecemeal manner, even though it also aims at achieving a systematic and comprehensive understanding of various sectors or aspects of nature.
IV. Science is not, and will probably never be, a finished enterprise, and there remains very much more to be discovered about how things in the universe behave and how they are interrelated.
V. Measurement is an important feature of most branches of modern science because the formulation as well as the establishment of laws are facilitated through the development of quantitative distinctions.

This list and others have sparked considerable interest in and emphasis on the processes of science as an important component of science teaching (2). Emphasis on the processes of science in teaching science has led to the development of inquiry teaching strategies. Those were introduced during the early 60s primarily by Schwab (20). Schwab and others extended this work considerably in the early days of the development of curriculum materials by the Biological Sciences Curriculum Study (BSCS). The technique was used in the "invitations to enquiry" which are presented in detail in the BSCS *Biology Teachers' Handbook* (10, 19).

Evelyn Klinckmann devotes a section of the second edition of the BSCS *Biology Teachers' Handbook* to the teaching of biology with specific information and analysis of a number of other teaching strategies which are as applicable in most other sciences and other

subjects as in biology (10). In section three of the handbook there are excellent discussions of teaching strategies and styles, discussions, readings, evaluations, field trips, and use of visual aids.

Some new and modified teaching strategies were developed along with the new curriculum materials that were developed during the 60s. These strategies not only were used by science teachers in the United States but by many science teachers in many other parts of the world. For example, a report by UNESCO advisers and consultants for the Institute for the Promotion of Teaching Science and Technology in Thailand includes a section of the role of inquiry in teaching the sciences (22). Included in this document is Table 1, page 161, illustrating a range of teaching styles and the involvement of students when such teaching styles were employed.

Although we have heard much about the teaching of science using inquiry techniques during the past decade or so, it should be recognized that teaching style is an individual matter and that any teacher will usually use more than one style during the instructional process in a given course. What needs to be emphasized and understood here is that the successful teacher will select and use a variety of teaching styles designed to be compatible with the nature of the students, with the school conditions, with the level and sophistication of the subject matter being studied, and the personal commitments of the teacher. In a very general way one might describe a good teaching situation as one in which a suitable blend of teaching styles is utilized to facilitate learning by the student.

Although usually considered in the context of evaluation (and with justification) the use of tests properly can be called a teaching strategy. The development of objectives, and tests to measure whether or not they are achieved, is fundamental in teaching science or any other subject. This observation takes on added importance when we realize the extent to which tests control what is taught. The following exchange is often typical and illustrative: "Teach, will we be asked that on the test?" If the teacher says "yes" the students often will learn that (mostly rote learning). If the teacher says "no" the students usually will not bother to learn that. Furthermore, if the tests that are used only test recall then the students' learning likely will not go beyond this cognitive level. If the tests are well-designed with a suitable balance which includes higher cognitive level questions, more meaningful learning can be expected.

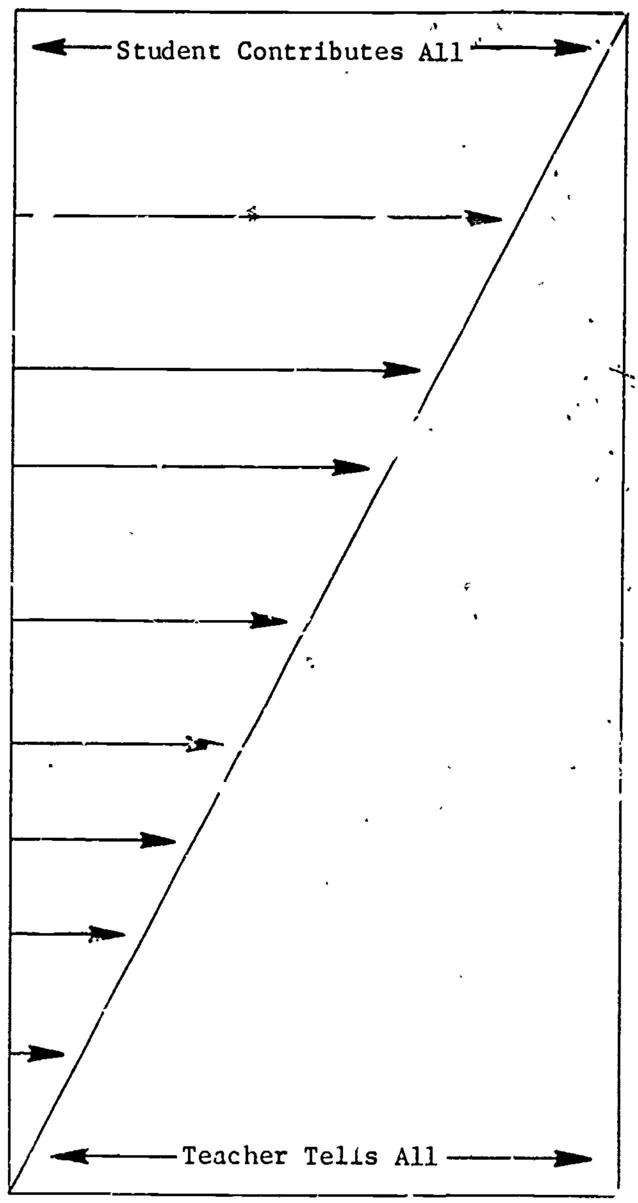
A number of the curriculum studies of the 60s included tests and booklets with pools of questions with a mixture of examples representing different cognitive levels. For example, BSCS has developed a *Resource Book of Test Items* for each of the three texts--blue, yellow, and green versions (3, 4, 5)--and earlier a book

Table 1.

Spectrum of Teaching Styles Showing Increased Student Contribution with Inquiry Method of Teaching

Teaching Style Examples

Student Contribution



9. Problem-centered activities. Define problem and variables. Formulate hypothesis. Design experiment. Test hypothesis.

8. Experiments with set methods which lead to open-ended outcomes and hypothesis formulation.

7. Student-designed experiments to test hypothesis.

6. Experiment with set methods to test hypothesis. Students asked to find answers : "key questions" asked.

5. Teacher demonstration as focus for inquiry questioning.

4. Data provided: Students guided to interpretation.

3. Lecturing with some inquiry questioning.

2. Experiments, set methods and observations with prescribed results.

1. Traditional lecturing.

Testing and Evaluating Student Success with Laboratory Blocks (12). Science teachers have long known that the interpretation of results from achievement tests in a given science course can be no better than the effectiveness or appropriateness of the test used to gain the achievement information. In other words, what we do is important and how we do it is important. However, the results from either of these activities is related to what we start out to do. If we design a test and include a large number of questions concerning trivial material (usually because it is easy to "test"), if we administer the test properly and score the test properly, then we would get precise results; but the precise results will be measurements of trivia and, therefore, of little consequence as a teaching strategy. The design and use of tests may be one of the most underrated skills and undertaught skills in teacher education programs.

As a component of science education the details of learning theory, like science, are also beyond the scope of this chapter. However, if science educators are not familiar with the ideas of B. F. Skinner, Jerome Bruner, Robert Gagné, Jean Piaget, and David Ausubel, they should at least know their reputations. Joseph D. Novak has pointed out that learning theory indicates that concept learning should be the focus of attention relative to the development of curriculum and instruction programs (18). Thus, teaching strategies and learning processes are necessarily interrelated.

RESEARCH AND DEVELOPMENT IN SCIENCE EDUCATION

One of the characteristics of any established discipline is the extent to which its practitioners have developed a body of research. In science education we have a fairly large body of research but the quality and usefulness of much of it is debatable. A great deal of the body of research in science education is contradictory or represents comparisons with no uniform basis. Successful teaching does not require uniform procedures. It has been noted earlier that teaching involves use of a variety of teaching styles designed to be compatible with the nature of the students, with the school conditions, with the level and sophistication of the subject, and the personal commitments of the teacher. Thus, it is easy to see why the results of teaching in one situation are not transferable to another.

On the other hand, if one compares recent research in science education with that done a decade or so ago it is clear that we have made a great deal of progress. We also have some obvious shortcomings. In general we have learned to write research papers clearly. We have learned how to design some experiments reasonably

well. We have learned how to select and use appropriate statistics. However, we have not done as well in the selection of useful or researchable problems.

In science education, it is probably more appropriate to consider a body of research and development. In science curriculum development, at least we have provided the teacher with many useful science teaching materials. The point has already been made that during the 1960s a number of specific new curriculum materials in many of the individual sciences were developed. These materials have made a considerable impact on science education--not only in the teaching of science but also in the development of additional new and different curriculum materials developed by the private sector as well as with government support. The point to be made here, however, is that these materials should constitute "working papers" for research and additional development; and thus they suggest one role of major importance for the evolving field of science education (11). In this process we should be involved with discovering new ways of transmitting both new and old scientific knowledge to students and to the public at large. This process will involve first the identification of the most important information and ideas in science at any given time and then the development of appropriate ways to communicate, adapt, and install such information and ideas in the schools.

It should be noted that while work is being done in the field of educational psychology and at the same time new curriculum materials are being prepared, there is relatively little interchange of knowledge from one area to the other. Research in science education ought to help bridge the gap between these two efforts. Research in science education should involve the implications of educational psychology research for curriculum development and likewise should use new curriculum developments as working papers from which to identify and characterize materials and techniques that could be used to structure teaching programs for optimum effectiveness. Similarly, the identification and application of factors involved in evaluation of curriculum materials should be included in science education research (11).

One of the areas in educational psychology that is particularly important for research in science education is the development and use of data gathering instruments. These include not only instruments for testing but also for other kinds of evaluation. It must be recognized that no research in science education can be any better than the tests or information gathering instruments that are used for the study. We need to recognize that it is not practical under most circumstances to prove that Class A is better than Class B or that Method A is better than Method B or that Teacher A is better than Teacher B. What we can do, however, is to set up appropriate

standards for the individual situations and determine the extent to which a given class, program, or teacher measures up to that standard. But we need appropriate instruments to make these determinations.

One of the obvious differences between research in science and research in education is that in science it is easier to control the variables than it is in science education research. One result of this situation is that in education we have resorted to more and more sophisticated statistical techniques to help deal with the uncertainty in our data. However, it must be recognized that sloppy or unreliable data cannot be made more acceptable through statistical analysis alone. We must recognize that no matter how appropriate or how sophisticated the statistical analysis may be, the research results are no better than the idea or the problem that is being investigated. If one investigates a trivial problem the results are going to be trivial regardless of the statistics used. We must start with ideas or problems that are meaningful, important, and researchable and use suitable techniques, materials, and instruments to research the problem.

Incidentally, another difference between research in science and research in science education is the availability of sophisticated and precise measuring instruments to be used in research in science. Although we now have many suitable techniques and materials for research in science and science education, we will continually need to develop new ones in both science and science education. In the field of science education we may need to rely on help from the educational psychologist or at least the foundation they have provided for the development of data gathering instruments.

In some ways research in science education parallels research in science. In terms of the major factors involved both may include

1. Identifying a problem.
2. Formulating of one or more hypotheses.
3. Designing a study.
4. Carrying out the study.
5. Interpreting the data or findings.
6. Synthesizing knowledge from the research.

The relationship of these factors is not always linear and all may not be explicitly shown in the publication of the research. These characteristics are reasonably true of both research in science and science education. However, they differ considerably in the following ways. As said earlier, in doing research in science we can usually control the variables in a much more effective way than in research in science education. We can manipulate the population or sample much more extensively in science research compared with science education research. We have more sophisticated

and accurate instruments to gather data and information in science than in science education. In science education we need to recognize these similarities and differences and, in particular, develop and explore new possibilities for controlling variables and for creating new and improved information gathering instruments.

THE FUTURE OF SCIENCE EDUCATION

What does the future hold for the field of science education? A current look at science education reveals that after a number of years of fairly rapid growth a plateau has been reached. It seems likely that science education will remain on this plateau for several years. It has resulted from a decrease in in-service science education, a decrease in the support for curriculum development, the anti-intellectualism attitude on the part of the public, and various problems in the economic and political sector. The public has become more critical of education and less willing to support many aspects of the educational enterprise including science education. It seems likely that we will remain on a plateau or at least have only a period of slow growth for some time to come. Even so, the future outlook is promising and the slow growth period may be more solid than the rapid growth one. We must learn to live with slow growth and adapt to it. Certainly one of the things we have learned in a study of evolution is that an organism must adapt to its environment or face extinction. We cannot replay old solutions--we must come up with new ones. For example, if we cannot get federal support for in-service training of science teachers perhaps we can get support from local schools or the private sector, although likely at a level less than that previously obtained from the federal government. Science teaching and the scientific enterprise is too important in the United States and other parts of the world for us to eliminate our innovative efforts to continue to improve science education.

What is the future environment in science education to which we must adapt or become extinct? It seems likely that in spite of certain specific criticisms the influence of social issues on science teaching will remain. So will the demand for accountability and the need to develop ways of determining accountability. The activities of science teachers in professional organizations seem likely to continue although an adjustment period may slow activities for awhile. The influence of teacher unions appears to be increasing and some adaptation to the considerably different way of life for union members compared with the teachers' way of life before involvement with unions will be required.

Although decline in interest for some programs and teaching strategies can be expected, a number of the innovations of the 60s are here to stay but with appropriate updating and modifications.

Curriculum development must not be allowed to become static. Curriculum development is never finished. It would be most unfortunate if after the successes of the 60s the scientists, science educators, and teachers packed their bags and went home. Both content and process have now been recognized as fundamental in science instruction--we cannot successfully teach one without the other. However, content must be constantly updated in terms of our current knowledge and social needs and we must constantly involve the processes of science in new ways if we are to expect maximum achievement in science teaching.

In a recent issue of the *Newsletter of the National Association for Research in Science Teaching*, the association president, Ronald D. Anderson, said:

> Implicit in the efforts of scholars in an applied field such as science education is the assumption that the results of their scholarship will influence educational practice. The expectation that change will occur is one of the motivations of the science education researcher. Optimism that such research-based changes are occurring today, however, does not seem to be particularly high. Evidence that research is influencing practice in science education is not abundant (1).

Anderson contends that this situation is because "scholars in the field of science education are not providing the broad conceptual framework needed as a rationale for classroom practice." He suggests further that the development of curriculum materials has often been based on a "particular assumption about the nature of science, the relationship between cognitive and affective learning, societal needs, or some similar matter" and not on empirically-based research. These are interesting ideas and may serve to guide future research in science education. On the other hand, it might be argued that curriculum development during the past decade or longer may well have had a greater influence on educational practice than the research that has been carried out during the same period.

Joseph D. Novak feels that new developments in cognitive learning theory could fuel a new boom to curriculum development, a cycle of improvement that can have even more impact on science teaching than that of the curriculum developments of the 60s (17). It may be that some of the research Anderson calls for could contribute to new developments in cognitive learning theory and thus provide a basis for new or better curriculum development. It is to be expected that the future of science education will include emphasis on both curriculum development and research.

The science educator clearly has an important role in the future. The science educator need not be a pseudo-scientist or a pseudo-psychologist but should have a working knowledge of both fields to carve an appropriate place in the broad spectrum of education by concentration on the teaching of science including the continued development of new curriculum materials, teaching strategies, and research relating to both. We should realize that working with young minds in the science classroom and laboratory may be just as important and exciting as discovery and inv. ion in the science research laboratory. Because of its influence on the science careers of many young people and, more generally, on the scientific literacy of the public, its importance to this country and the rest of the world cannot be overestimated.

REFERENCES

1. Anderson, Ronald D. "What is the Basis for Practice in Science Education?" *Newsletter of the National Association for Research in Science Teaching* 17(April 1976):1-2.

2. Bingman, R. M. (ed.). *Inquiry Objectives in the Teaching of Biology*. Kansas City, Missouri: Mid-Continent Educational Laboratory; Boulder, Colorado: Biological Sciences Curriculum Study, 1969.

3. Biological Sciences Curriculum Study. *Resource Book of Test Items for Biological Sciences: An Ecological Approach*. 3d ed. Boulder, Colorado: BSCS, 1973, p. 232.

4. Biological Sciences Curriculum Study. *Resource Book of Test Items for Biological Sciences: An Inquiry into Life*. 3d ed. New York: Harcourt, Brace & Jovanovich, Inc., 1973, p. 281.

5. Biological Sciences Curriculum Study. *Resource Book of Test Items for Biological Sciences: Molecules to Man*. 3d ed. Boulder, Colorado: BSCS, 1973, p. 249.

6. Brownson, William E. and Schwab, Joseph J. "The Textbook in Science Education." *The School Review* 71(1963):2.

7. Conant, James B. *Science and Common Sense*. New Haven: Yale University Press, 1951.

8. Glass, Bentley. "Theory Into Action--A Critique." *The Science Teacher* 32(May 1965):29-30; 82-83.

9. Hurd, Paul DeHart. *Biological Education in American Secondary Schools 1890-1960*. Biological Sciences Curriculum Study, Bulletin No. 1. Washington, D.C.: American Institute of Biological Sciences, 1961.

10. Klinckmann, Evelyn (supervisor). *Biology Teachers' Handbook.* 2d ed. New York: John Wiley & Sons, Inc., 1970.

11. Lee, Addison E. (ed.) *Research and Curriculum Development in Science Education, 1. The New Programs in High School Biology.* Austin: The University of Texas Press, 1968, pp. 9-11.

12. Le~ Addison E. *Testing and Evaluating Student Success with Laboratory Blocks.* Lexington, Mass.: D.C. Heath & Company, 1969, p. 285.

13. Mayer, William V. "The 9.2 Million Dollar Silence." *The American Biology Teacher* 37(October 1975):438-440.

14. Montague, Earl J. (ed.). *Research and Curriculum Development in Science Education, III. Science Teacher Behaviors and Student Affective and Cognitive Learning.* Austin: The University of Texas Press, 1975, pp. 19-27; 28-34; 51-54.

15. Morris, William (ed.). *The American Heritage Dictionary of the English Language.* Boston: Houghton Mifflin Co., 1970.

16. National Science Teachers Association. *Theory Into Action.* Washington, D.C.: NSTA, 1964.

17. Novak, Joseph D. Personal communication.

18. Novak, Joseph D. "Understanding the Learning Process and Effectiveness of Teaching Me hods in the Classroom Laboratory and Field." Paper presented at the International Congress on the Improvement of Biology Education, Uppsala, Sweden, September 8-12, 1975, p. 20.

19. Schwab, Joseph J. (supervisor). *Biology Teachers' Handbook.* New York: John Wiley & Sons, Inc., 1963.

20. Schwab, Joseph J. and Brandwein, Paul E. *The Teaching of Science.* Cambridge: Harvard University Press, 1962.

21. Spradlin, Susan D. "A Study of Change in Science Teaching Behavior in the Classroom Following Involvement in Institute Training or Retraining Programs." Ph.D. dissertation, The University of Texas at Austin, 1973.

22. UNESCO Advisers and Consultants. *The Role of Inquiry in Teaching Science.* Bangkok, Thailand: Institute for the Promotion of Teaching Science and Technology, 1974.

23. U. S. Congress. House. Library of Congress Research Report prepared for Subcommittee on Science, Research and Technology of the Committee of Science and Technology. *The National Science Foundation and Pre-College Science Education: 1950-1975*. 94th Cong., 2nd Sess., House, Document No. 61-660. [Washington: Government Printing Office, 1975.]

Ralph W. Lefler was born in Indiana in 1902. His elementary, secondary, and higher education was received in Indiana schools. After graduation from high school he attended three consecutive summer sessions at Manchester College. He then transferred to Indiana University and received his B.A. in 1926 and his M.A. in 1927. He did additional post M.A. work at Indiana University.

Mr. Lefler taught elementary school from 1920 until 1923 when he became a full-time student at Indiana University. After completing his M.A. in 1927 he served as a high school and junior college teacher of physics at LaSalle-Peru, Illinois, a position he held until 1943 when he joined the faculty of Purdue University as an instructor. He remained at Purdue until his retirement in 1971, having been promoted to Assistant Professor in 1947 and Associate Professor in 1960. He was awarded the rank of Emeritus Professor in 1971.

Mr. Lefler has been active in AAAS, AAPT, AETS, CASMT, NSTA, NARST, the Association of Science Education in England, the Indiana Science Teachers Association and the Indiana Academy of Science. He was elected a fellow of the AAAS and served as secretary-treasurer of NARST from 1971 until 1973, as president of NSTA in 1950-51, and as president of AETS in 1965-66.

In addition to his teaching duties in physics and science education at Purdue University, Mr. Lefler has been an active leader in physics education. He served as a consultant to the Indiana State Superintendent of Public Instruction for 20 years. He developed the Physics Teacher Workshop at Purdue University, which served as a valuable and unique resource for Indiana physics teachers. Mr. Lefler also directed numerous NSF summer institutes for physics teachers between 1960 and 1971. He also worked as physics adviser in Taiwan from 1957 until 1959 on a project for the improvement of engineering education.

Mr. Lefler has written numerous articles during his career which have appeared in education and science education journals. In addition he has authored or coauthored secondary physics education materials.

His service to science education has been acknowledged. is work with Cheg Kung University, Tainan, Taiwan, was recognized with an Outstanding Service Award from the Deans and Department Heads of the University. He was awarded a Citation for Distinguished Service by the AAPT in 1970 and in 1976 the NSTA presented him with the Robert H. Carleton Award for leadership in science education.

A BACKWARD LOOK THROUGH TRIFOCALS

RALPH W. LEFLER

Professor Emeritus of Physics and Education
Purdue University
West Lafayette, Indiana

In that which I will present here, I have taken a backward glance at some of what transpired during my teaching career which began in 1920 and extended to August, 1971. This is to give insight as to how things were. I shall usually leave it to the reader to note and evaluate the changes which have taken place. I believe the future to be in good hands and will neither make predictions nor suggestions.

I was raised on a farm in Indiana. My parents were hardworking, frugal people dedicated, among other things, to the education of their sons. I attended an eight-grade, one-room school with but one teacher during any one year. During the eight terms I had a total of six teachers, an indication as to their tenure; so far as I know none were forced to leave. I either heard or participated in the recitations of each class at each grade level eight times. This was a graded school which might now be called an open school. The subjects taught, texts used, and final examinations at each grade level were determined at state and county level. The final examinations for each year were graded by the teacher. At the end of the eight years I passed a comprehensive 8th grade examination, prepared at state level and offered and graded by the county superintendent of schools, and was graduated.

The teachers were good, earnest people who had had the equivalent of a high school education and 12 weeks to a year of study in a normal school. They were licensed as a result of having passed a state elementary school teacher's examination offered at intervals by the county superintendent.

Physiology and geography were the only science related subjects taught and these were descriptive.

Following grade school I attended a rural township high school which offered a minimum basic curriculum that included English, foreign language, history, mathematics, and science. There were

few electives. My interest in physics grew out of a one-year study of the subject, the only science other than general science offered during the years that I attended high school. I am certain that our teacher had never had a college course in physics but he was an intelligent person who could give us some insight into the subject. There were no demonstrations and no laboratory work. Our equipment consisted of a meter stick and a candle. However, my interest in physics was born in this class.

My first 12 years of school would seem very inadequate when viewed in the light of the offering today with broader curriculum, marvelous teaching aids, and well-prepared teachers. Actually I do not consider it to have been inadequate, just very different, however lacking it might be from the schools today. Discipline was good. Students took their assignments seriously. All my teachers were dedicated, although they were not members of professional organizations nor did they have professional journals. Professional meetings were limited to county institutes with meetings limited to three to five days per year. There were few diversions.

Students in those years might not have been able to pass some of the examinations regularly offered students today, however the world and society were much less complicated. I have grown into our present world gradually whereas students today are dumped into it with a sudden jolt.

Library facilities were nearly inaccessible to farm families. We had a few books in the home, one on natural history that my mother had studied and two periodicals, the *Pathfinder*, a weekly news magazine, and a daily county newspaper. In the grade school our only library consisted of a dozen books supplied by the state when I was in the 7th grade. I do not recall having found anything of interest in the minimum library at the high school.

Communication was slow. The newspaper came one to two days late by mail carrier. Long distance telephone was used only for dire emergencies. We did not have radio until I built a three tube set in 1922. My chief conveyance up to 1920 was a horse and buggy, although my father had purchased an automobile in 1912.

In the summer of 1920 and in the following summers of 1921 and 1922 I attended Manchester College. Although I studied the so-called normal school courses intended for those who were teaching in the elementary schools, the work transferred later to serve as the equivalent of the freshman year of work toward the B.A. degree.

In the fall of 1920 at age 18, with a high school diploma, 12 weeks of college work, and a one year elementary school license obtained by examination, I taught in a one-room, eight-grade school.

I taught as I had been taught. No one complained and those students who are still around are friendly. Following two added years of teaching grades 5 through 8, and the two summers of college work mentioned earlier, I entered Indiana University. At the end of four years I had completed my master's degree and was licensed to teach physics and mathematics at the high school level. My courses in education included one in physics methods taught by a physics professor who knew the "tricks of the trade." He taught me how to replace the gold leaves on an electroscope as well as some of the subtle characteristics which are the attributes of good instruction. He was himself a good teacher whom I attempted to emulate. I do not recall the other education courses as having been stimulating. The physics and mathematics courses were well taught, however the mathematics was usually taught as a tool which was a convenience to a student of physics.

My master's degree work was completed in a year and a summer and taken entirely in physics. Courses at both the graduate and undergraduate level were in classical physics with but one exception--a course offered in the summer of 1926 in modern physics. A thesis based on experimental work was required.

In the fall of 1927 I began teaching physics in a high school and junior college in Illinois. This high school was at that time a college preparatory school. Not until the depression years did we enroll a large percentage of the high school age group. When this happened our enrollment more than doubled and our faculty was absolutely jolted into developing a curriculum for all in the age group. Programs were designed for those who would not go to college but this did not affect the physics which consisted of a study of the basic principles in a theoretical way. Physics continued to be a college preparatory course.

In my early years of teaching, the laboratory work was largely cookbook style. The course had one merit--emphasis was on understanding so that ideas could be expressed in the student's own words and problems solved by the process of thinking that would have been necessary to develop the formulas so often plugged into by students in the solution of physics problems. Memorization of laws and plugging into formulas for the solution of problems was not the order of the day.

In June, 1947, I published an article entitled "The Teaching of Laboratory Work in High School Physics" in *School Science and Mathematics* (3). This outlines the evolution in laboratory teaching which took place during my 16 years of teaching physics in the high school. Starting with the cookbook, the laboratory eventually evolved into one in which students selected problems related to their course work for investigation.

Throughout the period 1927-1943 the junior college in which I taught offered the first two years of a four-year academic program. At the end of two years' study students transferred to a four-year college or university or terminated with an associate degree. No two-year programs of study designed as preparation for employment had been developed.

During these years the physics laboratory was usually open for two hours after school for students to do independent study using the library, apparatus, and facilities resource of the laboratory and the counsel of the teacher. I have often said that my best teaching was done after the end of the school day although I fully recognize that this was based on the foundation established by the more formal study. Students were also permitted to take apparatus and supplies home for use in their individual investigations, the requirement being that they must exhibit proficiency in the use of the apparatus taken on library loan.

In 1943 I joined the physics department at Purdue University as a physics educator. Although I taught sections of physics for engineering and science students my chief interest was in the preparation of teachers of physics for the secondary schools and in working with practicing teachers as a science counselor. One of my first assignments was to aid in the preparation of an *Outline for the Teaching of Applied Physics in Indiana High Schools* (4). This was published and distributed to all Indiana high schools by the state superintendent of public instruction. It emphasized a logical approach to the presentation and the use of demonstrations with simple equipment to supplement the meager laboratories in the schools.

Shortly after coming to Purdue I was given a joint appointment in the departments of physics and education. This was done out of a feeling by the administrators of the departments that each subject matter department should make an active contribution to the preparation of teachers in each academic area. While I was the first to be so appointed, there are now those in each academic area where courses are taught at the secondary level who hold joint appointments and who are responsible for the teaching of the methods courses and for the supervision of the student teachers. The joint appointment was also the result of a feeling in both the subject matter and education departments that those who served as school counselors or otherwise had contact with the schools should represent both interests.

Interest in the certification of teachers of science at the secondary level began in the early 1940s with the work of K. Lark-Horovitz who was then head of the department of physics at Purdue. This interest spread to national concern while he served as chairman

of the Cooperative Committee on the Teaching of Science and Mathematics. The committee in a report published in *School Science and Mathematics* in February, 1946, entitled "The Preparation of High School Science and Mathematics Teachers," recommended that one-half of the work leading to the baccalaureate degree to be in the academic areas in which the teacher would work, as for example, physics and mathematics (2). They further recommended that one-third of the requirement for the degree be in general education, and that the professional work, including student teaching, be limited to one-sixth of the course requirement. This early recommendation was further supported by the 1961 publication of *Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathematics* (1), a set of recommendations of the National Association of State Directors of Teacher Education and Certification Program and the American Association for the Advancement of Science ' ' /. Their recommendations became the established certification requirement for states such as Indiana where a 40 semester-hour major and 24 semester-hour minor were required in subject preparation. The professional education requirement was 18 semester hours. The remainder of the requirement for the bachelor's degree was in general education.

This recommendation stood from the mid-forties to the early seventies when it was severely challenged by those who felt that more time should be given to how to teach and less in the development of a basic competence in the subjects to be taught. It is probably well that I had retired before this movement got a good start for I would have contested it vigorously as I am sure many did. As I see it a teacher must be comfortable in his knowledge of the academic area in which he is working in order to give constructive attention to his teaching procedure. He must know what he wants to do before he can determine how to do it.

I am pleased that it was my privilege to serve with and participate in the work of the Cooperative Committee during most of its approximately 30 years of activity.

I had the privilege to work as physics (science) counselor in Indiana schools serving both Purdue and the Indiana Department of Public Instruction from the 40s until this activity was phased out in the 60s due to restrictions on travel and also due to the consolidation of schools. As a counselor I worked with both teachers and administrators on interests related to teaching content and method, on planning facilities, and on curriculum planning. This was a service welcomed by many of the smaller schools where the teacher might have only one class in physics and often times that only every other year, often alternating with chemistry. Thus, physics was only occasionally the teacher's chief interest. In contrast the teacher in the consolidated school of today will usually be scheduled from half- to fulltime in physics.

In 1946 Dr. Lark-Horovitz provided space in the physics building and asked that I develop a physics teacher's workshop. This differed from the science teaching laboratories at that time by being situated in a subject matter department rather than in the school or department of education. Although the student understood that this was a teacher education facility, its location helped him to retain contact with his colleagues in the academic area.

The physics teacher's workshop is an aptly-named laboratory which provides, in large part, the facilities needed by the high school teacher for the development of instructional skill and for his advanced study and professional growth. It is a laboratory for the development of ideas and for the preparation of materials to support instruction in physics. This workshop serves both preservice and inservice physics teachers. The preservice teacher becomes familiar with the nature of physics courses being taught in the schools and with the materials and techniques available to the teacher. The special methods course for the teaching of physics in the secondary school is conducted in this laboratory. The same instructor is also responsible for the supervision of student teachers of physics. Inservice teachers may use the workshop materials on a library loan basis.

A strengthening of the cooperative relationship between school and university has resulted from activity in the counseling program and the teacher's workshop.

In 1960 the department of physics established a curriculum leading to a non-thesis master of science degree for professional teachers of physics. This four-summer program of study had the support of the National Science Foundation (NSF) until they phased out their support of teacher institutes in 1974. More than 200 physics teachers have completed their M.S. degree in physics in this program and returned to service feeling very comfortable in their command of subject matter. This was an important program in that it allowed a teacher to do summer graduate study in physics; suitable physics courses were normally not offered during summer sessions. Under this program the teacher had the option of graduate study in his academic area or education.

Early in the 1950s I developed the Indiana Science Talent Search and the Indiana Regional Science Fair. Each of these programs was a firm counterpart of the respective national program. The purpose of these activities was not to bring fame or honor to the participants, their teachers, or their schools but to encourage a more stimulating approach to the teaching of science. Participation in the search or the fair required the student to conduct an investigation which involved some of the characteristics of research. While there is certainly a great difference in the degree

of sophistication of the problems which beginning students and seasoned scientists should attack, there need be no great difference in the nature of the approach or the attitude of the people who work on these problems. In the schools at the time so much of the teaching was rote and the laboratory work cookbook style that I felt it important to do something to encourage individual investigation by students. My work in these two statewide activities proved quite rewarding.

My last ten years before retirement were troubled years in America. They were years in which emotions ran high, in which we were, at the same time, concerned that Russia was getting ahead of us in science and technology and blaming science and technology for our ills, and in which the term *relevance* was much used without being clearly defined.

During this period there were numerous innovative course proposals with an aim toward presenting the basic concepts of physics in a logical sequence believed by their respective authors to be most effective for beginning students. It was hoped that these developments would increase student interest in physics and increase sagging enrollments. Millions of dollars of public money were spent on curriculum developments in the sciences and mathematics The results were markedly noticeable but not spectacular.

Two major curriculum developments with public financial support took place in physics: 1. Physical Science Study Committee (PSSC) and 2. Harvard Project Physics (HPP)--later Project Physics. Each produced texts and numerous valuable supplementary materials such as paperbacks, readers, apparatus, new stimulating ideas for laboratory experimentation, films, film strips, and overhead projection cells. These materials were widely used by all physics teachers regardless of the text selected. Although neither course was universally adopted each made a lasting contribution to the improvement of physics instruction.

It has always been my feeling that John Doe should teach Doe's physics rather than Physical Science Study Curriculum (PSSC) or some other named curriculum. He should be innovative and not a tape recorder. He should select from the available materials that he has access to--the material best adapted to his manner of teaching. This is now feasible for many physics teachers because of school consolidation and a subsequent reduction in the number of academic subjects which the teacher must prepare for instruction each day. It is likewise feasible because of the instructional aids made possible by both public and privately developed programs.

I am grateful to have lived and worked during a period which encompassed the first powered airplane flight and a walk on the moon. This among a multitude of other evidences makes me feel that although we have never taught science as well as we know how we have done a very respectable and admirable job.

REFERENCES

1. American Association for the Advancement of Science. Committee on Science Education and the National Association of State Directors of Teacher Education and Certification Programs. *Guidelines for Preparation Programs of Teachers of Secondary School Science and Mathematics.* Washington, D.C.: AAAS, 1961.

2. Lark-Horovitz, K. (chairman). "The Preparation of High School Science and Mathematics Teachers." American Association for the Advancement of Science, Committee on the Teaching of Science and Mathematics. Report 4. *School Science and Mathematics* 46(February 1946):107-118.

3. Lefler, R. W. "The Teaching of Laboratory Work in High School Physics." *School Science and Mathematics* 47(June 1947): 531-538.

4. Lefler, R. W., and others. *Guide for Teaching Applied Physics to Indiana High Schools.* Bulletin 139. Bloomington: Indiana State Department of Public Instruction, 1943.

George G. Mallinson was born in New York in 1918. His elementary and secondary education was obtained in New York State, after which he attended the New York State College for Teachers at Albany (now SUNY) from which he received his A.B. degree in 1937 and his A.M. degree in 1941. His Ph.D. was awarded from the University of Michigan in 1947.

Upon completion of his A.B. Dr. Mallinson served as a high school science teacher in New York from 1937 until 1940. He then moved to suburban Buffalo serving as a Science Department Head and Administrative Assistant until 1942. From 1942 until 1945 he was on active duty in the United States Army. During his graduate work at the University of Michigan he served as an assistant statistician. In 1947 Dr. Mallinson joined the faculty of Iowa State Teachers College where he remained one year. Dr. Mallinson then moved to Western Michigan University as an Associate Professor of Psychology and Science Education. He was promoted to Professor in 1949 and to Acting Director of the Graduate Division in 1953. In 1955 he became Dean of the Graduate College, a position from which he retired on January 31, 1977. He now holds the title of Distinguished Professor of Science Education and is serving as Interim Program Director of the Physicians Assistants Program.

Dr. Mallinson has been active in numerous state and national organizations including AAAS, NARST, CASMT, Michigan Science Teachers Association, Michigan Academy of Science, Arts, and Letters, and American Association of Workers for the Blind. He served as president of NARST in 1953-1954, president of the Michigan Science Teachers Association in 1954-1955, president of the Michigan Academy of Science, Arts, and Letters in 1970-1971, president of the Michigan Chapter of the American Association of Workers for the Blind in 1974-1975, and President of the Midwest Region of the American Association of Workers for the Blind in 1975-1976.

In addition to his regular university duties, Dr. Mallinson has taught as a visiting professor in over a half dozen major colleges and universities. He has directed more than 50 NSF institutes and programs and has been active as a consultant in the development of programs for the visually handicapped.

Dr. Mallinson has authored and coauthored several textbooks and textbook series. Since 1957 he has been editor of School Science and Mathematics.

Dr. Mallinson was recognized as a Burke Aaron Hinsdale Scholar by the University of Michigan. He was elected to Phi Kappa Phi, a scholastic fraternity, and Beta Beta Beta, a biology fraternity. In 1969 he was presented the Distinguished Alumnus Award by the State University of New York at Albany.

SOME NEW PERSPECTIVES ON AN ISSUE IN DOUBT

GEORGE G. MALLINSON

Dean, The Graduate College
Western Michigan University
Kalamazoo, Michigan

From modest beginnings in 1952 with a budget of $1,540,171 to a peak of $124,832,567 in 1969, the National Science Foundation (NSF) through fiscal year 1975 has expended more than $1,600,000,000 to improve science and mathematics education. These monies were allocated for various activities including institutes, traineeships, fellowships, course content improvement programs, leadership projects, talented student programs and conferences, as well as many others. The monies were allocated for these activities from the kindergarten through the university level and for natural science, social science, and mathematics. In addition, other agencies of government such as the National Aeronautics and Space Administration (NASA) and Department of Health, Education, and Welfare (DHEW) through various mechanisms such as the National Defense Education Act (NDEA) and the Elementary and Secondary Education Act (ESEA) contributed funds, a good portion of which were funneled into efforts to improve education in the natural and social sciences and mathematics. While no one ever expected that the millenium would be attained, there were reasonable expectations that significant improvements in teaching and learning in these fields would eventually become evident. It is indeed a sad fact that tangible accomplishments other than stacks of audited fiscal reports of expenditures, at least on an objective basis, have not been forthcoming. The saga of the efforts of the NSF since 1950 in seeking to improve science and mathematics education appears in a report prepared under the direction of Langdon T. Crane for the House Subcommittee on Science, Research and Technology (9). The details of the report are far too extensive to discuss here but several statements that appear in it are worthy of mention:

1. A review of the public record suggests that the National Science Board [the body that develops policy for NSF] may not have paid continuing attention to many important matters affecting the pre-college programs (9:11).

2. . . . the initial courses supported by NSF were proposed by, and came to be directed by, scientists with extensive research experiences and established scientific

reputations but with relatively little experience in the elementary and secondary classroom environment. This early trend led to some major success (highly debatable) but also created certain problems. Some of the early courses developed with NSF support were judged by schools to be too esoteric for a great number of students. Others were able to receive only limited distribution; local school systems were reluctant to adopt them because of their novel features, difficult content and need for extensive teacher training or retraining . . . (9:287).

Examination of early projects shows that review of content and intent of the program (referring mainly to the Course Content Improvement Program) was performed almost entirely by research scientists whose principal concern was for the substantive content of the course rather than for it's teachability, and who lacked familiarity with the milieu in which it would be used (9:287).

3. It would appear that recent criticism might be allayed if NSF were to avoid direct efforts to aid (sic) schools in the adoption of a new science curricula. It would seem that the institutes might well resume their former emphasis on modern methods of teaching science and on modern course content and avoid activities which seek to service the needs of particular schools or of particular school systems in adopting new curricula (9:209).

Parenthetically, I wonder why in the devil it took so long for someone at the federal level to come to such conclusions. One who had less than delightful experience in listening to Charles Whitmer and Richard Paulsen who set the tone for the earlier efforts in the Course Content Improvement Program of NSF as to what should be happening in elementary and secondary schools, and to some project directors who managed to wangle inordinate time at meetings of institute directors and space in journals to proselyte their programs funded by NSF was fully aware of what was going on, *as were many others*. But NSF was unresponsive.

I hasten to add that many of the directors and associate directors of institutes and other programs of NSF were appalled with the directives "from above" that forced them to become salesmen for book companies who managed to contract to publish programs that were developed with federal monies. But they were forced to follow the "party line."

Even worse was the academic prostitution of university faculty members who sought monies to survive during summers by submitting proposals to peddle commercially marketed programs whose development

was funded by NSF. I can name culprits in my own university so I am not only pointing my finger elsewhere. In other words many in the academic communities in science and mathematics "did anything if the price was right." They welcomed the opportunity to embrace PSSC, CBA, BSCS, ISCS, ESS, SAPA and other acronyms to their academic bosoms so long as they were paid salaries over the lean months.

But, to take only NSF to task is completely unfair since as one may infer from previous comments many in NSF were dismayed at what they were being forced to do to keep their jobs. Further, I wish to affirm strongly that I have been, and still am, a staunch supporter of much of what went on, and still goes on, in NSF. But I cannot "play dead like Rover" with some of what I have observed recently. Some history of what has happened may be relevant.

In the 1950s and early 1960s it was the "in thing" to castigate the failures of American education. There were shortages of scientists, science teachers, and other trained personnel in the technological fields. All of this was blamed on the American educational system. Those who wish to read "An Issue in Doubt" that appeared in the January, 1960, issue of *Educational Forum* will find that the excoriation and breast-beating within American society about sputnik and the decline of education in the United States were misdirected and basically resulted from the low birthrate during the depression of the 1930s and World War II (3). The birthrate was responsible for a lack of bodies to educate--a bedroom, rather than an educational, phenomenon.

In 1962 the program director of summer institutes of NSF and I spoke before the Midwest Conference on Graduate Study and Research and defended efforts of NSF to improve the teaching of science and mathematics in the elementary and secondary schools (7, 8). Fortunately, NSF had seen that the early thrust to provide monies for research had not been directed at the heart of the problem, namely a need to increase the cadre of well-trained teachers of science and mathematics.

But problems were looming on the horizon. In addition to the concern for producing the *means* to improve teaching, namely providing the education of teachers in the content, and to some extent the methodology, of science and mathematics, a movement developed rapidly to produce the *end*, namely development of science and mathematics curricula. Initially the emphasis was on programs for talented students, the first of which was Physical Science Study Committee-Physics (PSSC). But these burgeoned into many efforts in science and mathematics at all levels that allegedly were to lead to educational Valhalla. In the early years NSF stoutly denied any desire to provide any impetus toward the adoption of these programs. The body politic of NSF insisted that any publicity should indicate that

curriculum projects were *supported fiscally* by NSF *not sponsored or endorsed.* But power rests where the money is and those who participated in the development of such programs did all they could to imply that they were indeed morally supported by NSF as being the "right things to do in science and mathematics education." Unfortunately some of the staff of NSF did nothing to discourage such views. It becomes obvious that intellectual incest was emerging.

But another cloud was looming on the horizon. The content of many of the course content improvement programs was hideously inaccurate. I recall a seminar to which I was invited in Estes Park, Colorado, about 10 years ago to proselyte the Earth Science Curriculum Project (ESCP). The materials that were then in the final test editions defined *mass* as "an amount of matter" and indicated that the force of gravity was a function of the velocity of the earth's rotation at any particular location. When I challenged these and numerous other mythological statements in the materials I was informed that the narrative had been reviewed by a number of eminent scientists which, of course, was a lot of "meadow dressing." It was well known that a prestigious advisory group generally was appointed, attended an initial meeting at a handsome fee, and then was enshrined on the letterhead never again to be consulted. Without going into all the pleasantries that were exchanged, I did not lose the battle.

More recently a monograph prepared by the Council for Basic Education (CBE) published a thoughtful analysis of the Individualized Science Instructional System (ISIS) program (1). In effect it indicated that many of the flaws rampant in ESCP were evident in ISIS. Again it was indicated that the content developed with three million dollars from NSF couldn't be all bad since the project "sponsored by NSF and Florida State University" was investigated by a panel of experts who couldn't be wrong. It is difficult to challenge the experts particularly if they did not have opportunity, or perhaps did not choose, to examine the material carefully.

But the long-standing problems described in some excerpts from the report prepared for the House Subcommittee on Science, Research and Technology, indicated that all was not well "back at the ranch." Many of the curriculum programs despite massive funding by NSF and the Department of Health, Education, and Welfare (DHEW) were running into trouble. So long as federal money was available to purchase the programs and the hardware that accompanied the programs they were installed in the schools. The world "installed" rather than "taught" is appropriate since in many cases the purposes of the programs were nebulous and consequently disenchantment set in.

The equipment purchased at high cost with federal funds was stored in remote closets for later "cannibalization." The software was casually perused and in many cases discarded. But, as always happens, there was little introspection as to what might be inherently wrong with the programs. Consequently NSF policy shifted to correct the external factors that were viewed as being responsible for the difficulties. Probably, having invested vast sums for programs that "bombed" including PSSC, CBA, and others, NSF sought to defend itself. The fiscal support for science and mathematics education became "sponsorship" and, in fact, although not in a professed policy, only those proposals for institutes and other programs that were aimed at "brokering" the curricula that were developed with NSF funds were supported. But all of this did not occur without notice.

As Editor of *School Science and Mathematics* I wrote a number of editorials that chronicled the events (6), as did many others who watched the scene. And the scene wasn't pretty. Despite all the money that was frantically pumped into support of science and mathematics education as well as in other educational disciplines the expected increment of learning of students went in reverse. As summarized in a recent article it was indicated that since 1962-1963 the average scores of high school graduates on the verbal section of the *Scholastic Aptitute Test* (SAT) had dropped 44 points and on the mathematics sections 30 points (5). On the science section the decline was apparently minimal although one might reasonably expect that it should have increased. At this time, I want to emphasize vigorously that there is no intent to blame NSF for these decrements. As stated in my paper entitled "Summer Institutes as Graduate Programs"

> Without regard for the ultimate merit of these Institute programs, no other single activity has ever had a greater impact on American Education (7).

I still believe that statement without reservation and have the same attitude toward many other NSF programs. *But*, I heartily endorse the recommendation that appears in the report to the ninety-fourth Congress, to wit:

> It is recommended that the National Science Board initiate a study to develop new mechanisms for administering curriculum implementation activities that will allow the National Science Foundation to remain at "arm's length" from the process (9:297).

In other words NSF as well as other federal agencies should do as they profess that they intend to do, *support* the development of programs that seem to have educational possibilities but remain

completely aloof from tacitly or directly endorsing them. But all of this seems to be breast-beating and excoriation that leads nowhere. What should come next?

Suffice to say "the gravy train" with respect to support of education is over for the foreseeable future. The demands on the tax dollar have shifted from the needs of a youthful population to one that is growing older. More monies will be diverted, with good reason, into health and retirement and less into education, even on a per capita basis. But the needs for the support of graduate education is well stated in an article by Charles I. Lester citing a speech by Steve Bailey of the American Council on Education (ACE):

> What if the entire graduate enterprise in this nation shut down? Would it make an difference? It would make only this difference: The basic scaffolding of the intellectual and professional life of the nation would come tumbling down. At first, little change might be noticed. But ultimately, doctors would malpractice from ignorance; bridges designed by untutored engineers would collapse; literature and the performing arts would be held to no standards, and would dissolve into blobs of jelly; economics would become a broken record of inutile theories; philosophers would play sloppy word games without rules or vigor; astronomy would collapse into the black holes it has only recently discovered. The collective memory enshrined in our research libraries would dissolve into the aphasia of disuse. Above all, there would be no specially protected environment friendly to the restless probings of the human mind (2).

This does aggrandize graduate education but it is the truth.

The statement has many implications for graduate study in science and mathematics education as evidenced by data in a longitudinal study by the author in which one facet was to determine the relationship between graduate study of science and mathematics by teachers and the achievement of their students in these areas (4). The study indicated clearly that the undergraduate background of teachers bore little or no relationship to student achievement in science and mathematics whereas their graduate study in science and mathematics was significantly related to student achievement in these areas. Since the graduate study was undertaken during the "heyday" of institute programs one can hardly ignore the merits of the contributions of NSF institutes to student achievement. But there is always some question as to how much impact a valid conclusion of a research study has compared with the statements of a bombastic, director of a project funded by NSF, particularly when the statements are made on an NSF platform. But all this is the "mouthing of babes"

when one views what lies ahead. So the question remains "What is likely to happen next?" I am perfectly willing to go out on a limb and make a number of statements, many of which are in the realm of conjecture and many of which are not. So let's get to business.

1. A *major* factor in the adoption of programs for science and mathematics (books, kits, and other miscellany) will be cost. No longer can programs for teaching in science and mathematics involve excessive costs of equipment. "Excessive cost" may well be defined as the difference between the price of a beaker (75¢ or more) and that of a baby food jar (0¢) when both can serve the same function equally well. If it can be done with scrap material nobody will be willing to pay for the expensive hardware. Without going into all the details some of the most effective science and mathematics programs have been implemented with the materials for activities ("experiments") that children scavenged from somewhere to bring to school.

2. The alphabetic programs, despite the alleged assertion of Jerrold R. Zacharias that PSSC would be the physics program in 80 percent of the schools by 1970, will disappear. I firmly believe that the good and evil they did will influence the content of science and mathematics programs in the future. But the acronyms will be absent.

3. Some types of programs of the institute variety will be initiated by NSF. But the programs will be dictated by cost effectiveness, a highly salutary development. The AAAS-NSF Chautauqua-type short courses may well serve as models since they have been highly effective. These programs have run for two full days of eight hours each in the fall followed by an intervening period of about three months during which the participants are asked to complete a project relevant to the program. This interim period is followed by another two-day session in the spring during which the projects are reviewed and the program is tied together. In some instances credit is available for completion of the program. Such credit is quite legitimate and does require that the participant pay the cost of tuition.

4. The funding of participants for subsistance and travel for summer institutes is probably, and should be, "done gone." The urge to get *more* qualified teachers has subsided for reasons that are too numerous to mention here. But the end of the quest for numbers is eminently worthy. If indeed institutes reemerge, and well they should as a function of continuing education, they are likely to be of the inservice variety in which costs are minimal.

5. The Crane report indicates rather clearly the disenchantment of Congress with NSF policy. Continued funding is obviously likely to be on a more rational basis where entrepreneurs can no longer feed on the federal trough for implementation and royalties. The latter point may be contested vigorously but the money was made in many cases by such entrepreneurs through the establishment of dummy corporations only through which the equipment for the acronym programs could be purchased. So the facade of integrity was preserved, even if somewhat tarnished.

6. Without disregarding the importance of the skills of inquiry, more balanced consideration will be given to content. But the emphasis will not be on the long-since discredited Bronx High School of Science approach, namely to stuff talented students with twice as much of what they shouldn't have been stuffed with in the first place. Rather, science and mathematics content will be more consistent with the Research Related to National Needs concept (RANN) including environment management, use of energy, and what has long been disregarded--materials science. Anyone with any vision is aware that the energy crisis in which we are now involved is a Sunday school picnic compared with the materials crunch we are going to face within the next decade. Many materials on which we are highly dependent are being processed from less productive ores and some are almost completely supplied from foreign sources. The Arab oil syndrome will no doubt influence the current suppliers of these crucial materials.

But one could go on and on listing problems--an easy, heartwarming, but relatively unproductive, intellectual exercise. The real task is to come up with solutions that are feasible. They will, however, be less pleasant than those solutions with which we have "lollygagged" for so long. We have talked about processes of science and in a heady euphoria have developed *integrated* rocesses of science both of which, as one could predict, went over like "lead balloons."

The point being emphasized here is that *science* in the elementary and secondary schools and that with which average citizens need to cope should be the underpinning of the objectives of much of the science teaching in colleges and universities. We can no longer indulge in the luxury of sanctifying ourselves as apostles of science for science's sake course improvement projects. We'd better realize that these academic exercises are dead, in fact, "stone cold dead in the market." Except to blithering idiots this was evident years ago. We are now, as we were then, in a market where a practical approach is *not* "beneath the dignity of a gentleman." In other words the consumer approach will need to be reviewed with vigor.

7. Above all it is extremely unlikely that any efforts in the future similar to the Course Content Improvement Program will receive monies with which to proselyte new programs. Undoubtedly any programs in the future will place emphasis on teachability rather than on rigid conceptual or process structure.

8. As a final note, I wish to affirm vigorously that the new directions *that will take place, come hell or high water,* will no doubt be exploited by entrepreneurs whose mouthings will emphasize "meeting the needs of society" when they are really oriented toward filling the pockets of schills who exemplify *The Emperor's New Clothes*. There are many dedicated persons at all levels who are confused as to what is going on. Who isn't? The solution, however, is not going to be provided by those who peddle experiences at a profit, with vast amounts of credit, for minimal effort. The success will be accomplished by the little guy who teaches science in the rural community, suburb, or ghetto who really believes in what he is doing. He will not be one of those who flee school at 3:00 p.m. He will stay behind because he loves teaching science and students and is willing to give extra time. He will not leave because his profession is a chore.

REFERENCES

1. Dunkham, William W. "ISIS: The Container as Contents." *Council for Basic Education Bulletin* 20(April 1976):1-7.

2. Lester, Charles T. "Speculations Concerning the Future of Graduate Education." *Graduate School Review* 19(Spring 1976): 1-5.

3. Mallinson, George G. "An Issue in Doubt." *Educational Forum* 24(January 1960):147-156.

4. Mallinson, George G. *Final Report on Science Motivation Project I, Cooperative Research Project 503: An Analysis of the Factors Related to the Motivation and Achievement in Science Courses in the Junior and Senior High Schools.* Washington, D.C.: Cooperative Research Branch, Office of Education, Department of Health, Education and Welfare, 1963, pp. v, xvii, 177.

5. Mallinson, George G. "It's Time for a Second Coat." in The Guest Room, *The Virginia Mathematics Teacher* 2(February 1976): 6-8.

6. Mallinson, George G. The following articles have appeared in *School Science and Mathematics*. "The National Science Foundation and the Public Domain" 64(October 1964):569-573; "The Schaghticoke Powder Mill Blew Up and the Rooster Ain't Crowed Since" 65(November 1965):675-676; "Laurels and Larceny" 65 (December 1965):761-762; "Are Schaim's Statistics Sloppy?" 68(June 1968):471-472; "You Been a Good Old Wagon But You Don Broke Down" 72(February 1972):105-106; "Pants Full of Snakes and Bottles of Whiskey" 72(April 1972):279-280; "It's Such a Nice Day for a Funeral!" 73(October 1973):529-530; "Oh Where Did All the Money Go?" 74(April 1974):265-366; "I Had It, But It's All Gone Now!" 74(November 1974):557-558.

7. Mallinson, George G. "Summer Institutes as Graduate Programs." *Proceedings of the Eighteenth Annual Meeting of the Midwest Conference on Graduate Study and Research.* Iowa City, Iowa: The Midwest Graduate Study and Research Foundation, Inc., pp. 17-29.

8. Morrell, William. "Discussion." *Proceedings of the Eighteenth Annual Meeting of the Midwest Conference on Graduate Study and Research.* Iowa City, Iowa: The Midwest Graduate Study and Research Foundation, Inc., 1962, pp. 29-34.

9. U. S. Congress. House. Report prepared for the Subcommittee on Science, Research and Technology of the Committee on Science and Technology. *The National Science Foundation and Pre-College Science Education: 1950-1975*, ed. Langdon T. Crane. 94th Cong., 2nd Sess., January 1976. [Washington, D.C., pp. x, 297.]

Elsa Marie Meder was born in 1909 in New Jersey where she acquired her elementary and secondary education. After graduation from Westfield High School she attended Columbia University from which she received all her degrees: her A.B. from Barnard College in 1930, her A.M. in 1932, and her Ph.D. in 1942.

After completing her A.B. in 1930, Dr. Meder worked as a laboratory assistant at Yale Medical School, as a chemical librarian for E. R. Squibb, and as a secondary school science teacher in New Jersey. In 1939 she enrolled in Teachers College, Columbia, for graduate study in science education. While there she served as instructor and as research associate in the Bureau of Educational Research in Science. In 1944 she was appointed assistant professor at Jersey City State College, but soon went to Washington as a member of the editorial staff of the Armed Forces Institute. When World War II ended, she joined the high school department of Houghton Mifflin Company with responsibility for mathematics and science textbooks. She remained there until 1960.

From 1961 until her retirement in 1973, Dr. Meder was involved in international education. From 1961 until 1969 she worked through Teachers College, under its contracts with the Agency for International Development and the Peace Corps. She was a lecturer in science education at Makerere University, Uganda; she worked with American secondary school and college teachers in East Africa as a liaison with Teachers College, A.I.D., and for Peace Corps; she directed and participated in training programs for Peace Corps teachers for East Africa; she worked with the Ministry of Education of Afghanistan, setting up a curriculum development and textbook project for the elementary schools of that country. In 1970 Dr. Meder became a Peace Corps official, serving first as training coordinator for the Africa Region and later as program representative and director of Peace Corps in the Gambia.

Before her involvement in international education, Dr. Meder published articles on science education in Science Education, in the Review of Educational Research, and in the Teachers College Record. For several years she served as voluntary editor of Science Education. Her dissertation was published by the Kings Crown Press under the title Youth Considers the Heavens.

At present her major educational activities are membership on the Board of Trustees of Saint Francis College of Maine and participation in the work of school committees in the village in which she lives.

WE COME TO LEARN

ELSA MARIE MEDER

Kennebunkport, Maine

On the first Friday in May of 1961 a group of members of the Association for the Education of Teachers in Science (AETS) held a meeting in the Graduate School of Education of Harvard University. What transpired at the morning session that day I do not recall nor, I am sure, do many of those who were in attendance, for that was the day on which Alan Shepard became the first American to be hurtled into space and the AETS session recessed without much formality so that those present could witness the television coverage of the event. Perhaps others who were there can remember what happened when the meeting reconvened after lunch but I never really knew because during lunch Hubert Evans, then at Teachers College, Columbia University, had suggested that I become a visiting professor at Teachers College for the purpose of being seconded to the Faculty of Education of Makerere University College in East Africa. The unexpectedness of the suggestion and its to me incredible nature made it impossible for me to follow the proceedings of the meeting with anything more than the appearance of attention. Before two months had passed I found myself in Kenya, and my life has not been the same again. One way or another I have been involved ever since with education in what are usually called developing countries: with Teachers College, under Agency for International Development (A.I.D.) contracts, and with the Peace Corps. The years have been crammed with learning experiences I could never have imagined and it is these experiences which have determined the title of this paper. Westerners working overseas in development projects including Americans who serve as Peace Corps volunteers are successful, I believe, to the extent that they are motivated to learn as much as they can while there and at the same time to make some recompense to the people of the country for the richness of the opportunities that are theirs.

AFRICAN LESSONS

As a teacher one of the first lessons I learned was the inadvisability of attempting to follow familiar procedures and the practical impossibility of doing so successfully except by chance. Or to state the same idea more positively, I learned as never before the essentiality of selecting content and method in terms of particular situations and particular students. Of course, such selection involved understanding the situations and the students; in my case, understanding unfamiliar cultures and their impacts upon the students who were their products. Understanding, real understanding, is probably impossible under such circumstances. But one can strive for empathy rather than aloofness, for respect of strange customs instead of disdain or fear, and for humility instead of arrogance. These are qualities which can be cultivated-qualities which we all know are among the most valuable assets a teacher can have. The cultivation of them pays immeasurable dividends not only in making it easier to do the job of teaching but in opening exciting new vistas, new fields of learning.

The young Africans in my Makerere classes had studied and were preparing to teach science courses according to the Cambridge syllabuses. For many reasons they and their teachers had seldom sought illustrations in local life of the principles listed in the syllabuses. Even less frequently were those principles derived from the multiplicity of relevant data at hand.

I well remember walking with a few of my students along a footpath leading to a small outlying village. They were enjoying their self-imposed task of introducing me to things along the way which they believed to be unfamiliar to me (and needless to say, I was enjoying their efforts). We came to a lone mud hut, empty for the moment. They investigated and found that it was the workshop of the village blacksmith. We entered and the students began to tell me how the smith worked. I asked a variety of questions, some because the smithy was indeed unfamiliar to me and some because I could not resist acting like a teacher: What does he do with this (the bellows)? What is the point of forcing air in that way against the charcoal? Suddenly one of the young men saw the linkage between the blacksmith's procedure and a Cambridge syllabus topic he had memorized long before: "The combustion of carbon in limited and copious supplies of oxygen." He quoted the syllabus gleefully and then added, "And that chap doesn't even know it!"

Textbooks have sections on the metallury of iron and steel and commonly include among the illustrations a cross-sectional drawing of the Bessemer converter with some such comment as this: "Bessemer steel is used for making machinery, tools, wire, and nails, and is the essential modern structural steel used in steel framework

buildings" (1:209). Bessemer developed his process during the 1850s and was knighted for his achievement in 1879. But for ages past, ironworkers of southwestern Uganda had been using a smelting process essentially the same as Bessemer's--when I show a cross-sectional drawing of their kiln to Americans, they think they are seeing a drawing of a Bessemer converter (4:29-36). And from the resulting steel these craftsmen make thread-like wire; a steel bar five or six centimeters in diameter and less than a meter in length can be drawn out into some 50 meters of wire. The process, of course, is not automated. What is accomplished in 20 minutes in the United States or Great Britain requires several days for these African ironworkers; but the metallurgy is the same.

This story illustrates another of my African learnings: not only do all cultures, even very "primitive" ones, have their craftsmen but sometimes the technologies of these craftsmen can be relatively sophisticated.

The remark which the young man added to his syllabus quotation was not intended as praise for the smith's practical knowledge.. Too often the educated person in a land where few have schooling looks down upon his uneducated countrymen. Similarly, we of the "developed" world sometimes act as if our technological civilization justifies us in derogating simpler cultures and their adaptations to their environments.

The importance attached to book learning in lands where it is a rarity is closely related to dependence on the authority of the printed word. Such dependence, as we know, is by no means peculiar to third-world countries. We all have heard of the Christmas newspaper editorial, "Yes, Virginia, there is a Santa Claus"--Virginia had written to the newspaper because her father had told her, "If you see it in the *Sun*, it's true." Although few persons place as much reliance on a newspaper as Virginia's father did, there are many to whom a statement in a book, especially a holy book or a textbook, is to be accepted unquestioning. It is often hard to sow the seeds of an appropriate skepticism.

Let me use another illustration from my Makerere classes. One young man was preparing to teach his first lesson to a junior secondary school class and had been assigned, by the regular class teacher, the syllabus topic dealing with frogs. He had studied the textbook and had made an outline; now he was practicing on his college class. As so many first-time teachers do he soon started lecturing, and in the course of his lecture he announced that frogs hibernate in winter. No one in the grou saw anything amiss; they too had read the textbook. All were a b.t surprised when I asked, "When is winter?" After a brief silence one student said tentatively, "You know when winter is." I ag..eed that I knew when winter

occurs in New England but justified my question by saying that I would not know how to answer a junior secondary pupil in a school half a degree north of the equator if he should ask me the question. This stimulated considerable discussion, during the course of which the very polite college students forbore to tell me that no junior secondary school pupil they knew would ask his teacher such a question.

I do not fault these African students very seriously. When one must do all one's studying from books written in a foreign language and prepared primarily for students in a different part of the globe the temptation is great to accept the words of the book, whether or not they are in line with one's own experience. Nor is it quite the same thing for an African to study in English (or in French) as it is for an American or a Briton to pursue his arts and sciences studies in French or German. This is true not primarily because of the many English words derived from French and German nor because of the historical development of the European languages; but because of the basic differences in the cultures of which the languages are expressions. Students of linguistics recognize that there is a relation between the language of a people and their ways of conceiving of the world. Thus there are inescapable complications in communication not only because of vocabulary inadequacies and varying connotations of worlds that convey abstract meanings but more fundamentally because of differences in values and world views.

AFRICAN WORLD VIEWS

This paper is not the place, and I am not the person, to attempt an analysis of African value systems and world views. The continent is large, its cultures many. But there are recognized basic similarities in world views (4:253ff). African ways of life are everywhere associated with the concept of the family. The African family is not the nuclear family of the West but the extended family of biological kin in which each has his responsibilities and privileges and few if any feel unwanted--a model for wider and wider societal relationships. By extension, unrealized and perhaps unrealizable, the African concept of the family seems to trend toward the ideal of the family of man.

Since the family extends backward in time as well as forward and in ever widening circles, African ways of looking at life include continued recognition of ancestors, family members who are no longer to be seen upon the earth. But it is the earth itself, the land, which is perhaps the most significant component of the African world view. The land provides that which is needed for living--to the farmer, to the herder, to the hunter, to the craftsman. The land is the parent of all people.

All this has been summed up in three sentences:

Man and his surroundings are one.
Man and his past are one.
Man and other men are one (4).

I do not think we can sum up a western viewpoint in similar statements. Yet the African nations today are striving for development along western lines; they are committing themselves to our kind of progress. They accept as fact their need to learn from us. I keep hoping that we will recognize our need to learn from them. If there can be mutual learning, perhaps we in the West can escape from the technological trap symbolized by the word *pollution* and can move more and more toward policies premised upon human needs in an effort to bring about, at long last, "freedom from want . . . everywhere in the world" (5). If there can be mutual learning, perhaps the African nations can move toward their goal of economic development without sacrifice of their traditional strengths.

Few indeed are the prophets who prophesy with total accuracy. In 1780 Benjamin Franklin wrote to Joseph Priestley, prophesying in part, envisaging technological progress without penalty, dreaming of that which some of us would never desire; and expressing at the end a wish toward which we still must strive--as scientists, as teachers, as citizens. Here is a part of his letter:

> The rapid Progress *true* Science now makes, occasions my regretting sometimes that I was born so soon. It is impossible to imagine the Height to which may be carried, in a thousand years, the Power of Man over Matter. We may perhaps learn to deprive large Masses of their Gravity, and give them absolute Levity, for the sake of easy Transport. Agriculture may diminish its Labour and double its Produce; all Diseases may by sure means be prevented or cured, not excepting even that of Old Age, and our Lives lengthened at pleasure even beyond the antediluvian Standard. O that moral Science were in as fair a way of Improvement, that Men would cease to be Wolves to one another, and that human Beings would at length learn what they now improperly call Humanity (3)!

REFERENCES

1. Bridgwater, William, and Kurtz, Seymour (eds.). "Bessemer Process." *The Columbia Encyclopedia.* 3d ed. New York: Columbia University Press, 1963.

2. Castle, Edgar B. Personal communication.

3. Fleming, Thomas (ed.). *Benjamin Franklin: A Biography in His Own Words.* Vol. II, *The Founding Fathers.* New York: Harper & Row, 1972.

4. Turnbull, Colin M. *Man in Africa.* Garden City, N.Y.: Doubleday, 1976.

5. U. S. President, 1933-1945 (F. D. Roosevelt). Message to Congress, January 6, 1941. [Washington, D.C.: 1941.]

Milton O. Pella was born in 1914 in Wisconsin where he received his elementary and secondary education. After completion of his secondary education he attended Milwaukee State Teachers College from which he received his B.E. degree in 1936 His graduate work was done at the University of Wisconsin-Madison from which he was awarded his M.S. in 1940 and his Ph.D. in 1948.

Following his graduation from Milwaukee State Teachers College he taught in Wisconsin elementary and secondary schools. In 1939 he accepted a position at the University of Wisconsin High School where, except for four years of military service from 1942 until 1946, he taught until 1956. He has been Professor of Science Education at the University of Wisconsin since 1948.

Dr. Pella has been active in numerous professional organizations including NARST, NSTA, AAAS, CASMT, AETS, Wisconsin Society of Science Teachers, and the Wisconsin Education Association. He served as president of CASMT in 1955 and as president of NARST in 1966. He also served on the Board of Directors of NSTA.

In addition to his regular teaching, research, and service duties at the University of Wisconsin, Dr. Pella has been active in international education. He has served many foreign countries, helping them to establish research and development programs in science education. This activity has involved developing programs of training as well as assisting in research. His science education service has included the countries of Costa Rica, Egypt, India, Iran, Jordan, Lebanon, Nigeria, Saudi Arabia, Syria, and Turkey.

Dr. Pella has also actively participated in the planning, conducting, and administration of NSF institutes for science teachers and supervisory training in science education and in USOE programs for research training in science education from 1956 until 1970.

Dr. Pella has been an active author and researcher for more than 35 years. He is the coauthor of several textbooks and textbook series in science and mathematics as well as other learning aids. More than 50 of his articles and research papers have appeared in education and science education journals. He has also served on the editorial boards of several science education journals.

SCIENCE TEACHING

MILTON O. PELLA

University of Wisconsin
Madison, Wisconsin

Throughout the last three-quarters of a century educators have agreed in varying degrees that science plays an important role in general education. Why it does, what science, how much science, where in the curriculum the learners are exposed to science, how science is to be taught, what contributions science learning makes to personal and social welfare have produced volumes of dispute, only a trickle of ideas, and no principles of reasonable credibility. Throughout this time we have been besieged with volumes of opinion-based expositions and one-time "research studies" that hardly qualify as pilot studies relating to science teaching.

The words to the song of objectives and teaching methods have changed slightly but the tune has remained essentially unchanged for the past 40 years. The following topics have been the subjects of infinite numbers of pages of words:

- Discovery learning written about in 1916--the pupils "reasoned from their own experiences"; no books were used.
- The science curriculum must be examined in terms of the needs of individuals in a rapidly changing society--1916.
- Humanistic science teaching--1916.
- Project teaching--1916.
- There is need for scientifically trained personnel no less in peace than in war--1920.
- Sex education and social hygiene--1920.
- The laboratory in science teaching, science and technology, science in an integrated curriculum, multimedia instruction, logical vs. the psychological approach to learning--1920.
- The heart of science is the scientific method.
- The most important outcome of science teaching is the development of the scientific attitude.
- The objectives are stated as desirable behavior changes.
- The teaching of science is to develop abilities in problem solving and critical thinking.

The following is by no means an exhaustive list but should reveal the same old stuff with new words: inquiry, discovery, process, affective domain, interactions of science and society, structure of the discipline, humanistic approach to science teaching, cognitive approach, behavior objectives and so on.

RECURRENT PROBLEMS IN SCIENCE EDUCATION

To review the problems and issues of science teaching over time, one need only to read the volumes of the *General Science Quarterly* (which became *Science Education* in 1928), *Science Education, School Science and Mathematics*, and the *Journal of Research in Science Teaching*. The above problems and many others are found consistently and uniformly except for a change in the orientation of those who write. During the 1930s and immediately following the publication of the National Society for the Study of Education's (NSSE) Thirty-First Yearbook there were the academic scientists who were pleading for better science instruction (1). Soon this population of authors changed to those who worked in both science and education, Charles Peiper, Wilbur Beauchamp, Samuel Powers, Earl Glenn, Walter Whitman, William Eikenberry, Francis Curtis, Clarence Pruitt, Ellsworth Osbourn, Ira Davis, Bertha Parker, Harry Cunningham, and Gerald Craig. This group, qualified in the academic disciplines and interested in the pedagogy of the disciplines, tended to reproduce itself to a limited extent.

The science teaching of this era was that of relating science to community and personal living. In a book series of 1935 it is stated that for grade 7 the concern should be for simple knowledge of the useful and interesting science in the immediate environment; the second year understanding should be the goal; and in the third year interpretation and application should be the goals. We continue to use the same terms today.

With the extraordinary demands on science education around 1957 the label *science education* became the ticket to many theaters. With this demand came an increase in the number of the "camp followers"--the educationists who were informed in education-ese and educational psychologists who had some hypotheses and wanted a place to use them--seeking the opportunities in science and mathematics.

Science teaching soon came into the hands of three groups: educationists and educational psychologists, science educators, and scientists. It seems that the three groups have indulged each other during the past 20 years to such a degree that science education is now in a state of chaos. The educationists and educational psychologists are selling discovery learning, process teaching, interests, cognitive learning, and attitudes. The scientists have

been selling science for the sake of science to make big scientists and little scientists. The few science educators left are pleading for a place in the sun because the best attention they get is from science for literacy. The science educator finds himself identified with the two other groups to the extent that he has no ground of his own.

The educationists and educational psychologists use science as a vehicle for testing their hypotheses. The science educator, on the other hand, is concerned with the pedagogy of the particular concepts, laws, and protocols of the several disciplines.

The growth of science education during the past 40 or more years has suffered from ailments that are complex in functional relations. I believe that educational research based upon educationese and/or psychology of learning and development has produced essentially nothing in the way of improving learning. This is not to say that all of our activity in the past is useless but rather that our activity should help to show what not to do; this is progress.

Some of the what-not-to-do things are listed for consideration by the future participants in research in science teaching. Past studies have assumed that there is a learning procedure common to all conceptual knowledge. It has even been called *concept learning*. Now we know that all concepts in science are not of the same species. It is suspected by some that concepts, since they are content specific, are thus learning specific. Studies should thus relate to specific procedures designed for learning individual concepts at a specific level of comprehension.

In the past the people in science education, some scientists, and most teachers assumed that knowledge in science develops as a consequence of following the "scientific method" which employs inductive procedures. (This may be the source of the idea that knowledge in science is discovered just as Columbus discovered America.) It seems, however, that knowledge in science has been created utilizing hypothetico-deductive processes; it is not discovered. This change in attitude or belief still escapes even some college teachers of science.

It is obvious that the acceptance of these two ideas could change the teaching of science and studies of the teaching of science very dramatically. It seems that the basic assumptions of the nature and evolution of knowledge were and in many cases still are in error. From erroneous assumptions can only come meaningless generalizations.

Another serious problem in science teaching and science education has its origin in the vocabulary of the area of interest. The vocabulary has been selected, often indiscriminately, from

engineering, science, metaphysical philosophy, philosophy of science, logic, economics, mathematics, medicine, and so forth, and prostituted to the point where any one word, regardless of context, represents as many concepts as people wh[illegible]. Advertising psychology in the form of catch phrases or [illegible] has been substituted for the objective examination of the structures and functions of science. How these relate to what little is hypothesized about how people learn, and the relationship between experiential maturity and complexity of learning is not being considered.

Today there is no list of objectives for teaching science. To some the objectives are cognitive, to some conceptual, and to some a mixture. All groups probably have at least one objective that is affective. The terms of old--*inquiry learning, discovery learning, learning how to learn, problem solving, humanistic education, inductive teaching and learning, critical thinking, scientific attitude,* and so forth are still with us and after more than 40 years are still undefined.

During the past 40 years the study of science in the schools has moved from extreme use of reading as a learning procedure to what seems to be conscious effort in science classes to protect the pupil from exposure to the printed page. It seems that the "new programs" especially at the elementary and middle school levels no longer see the function of reading in learning science.

The use of laboratory activities is now extreme at all levels. This in spite of the fact that really modern science is very limited in terms of bench-type activity. This in spite of the fact that scientists no longer look upon their activities as discoveries utilizing inductive procedures. This in spite of the fact that more research comes from the utilization of existing data and the creation of ingenious computer programs. This in spite of the fact that most learning after the individual leaves school comes through reading. This in spite of the fact that there is a difference between the practice of science and the teaching of science. This in spite of the fact that most science teachers are not scientists. This in spite of the fact that very few students in science classes will become scientists or technicians. It is even possible that the excess use of the laboratory activities may lead to overconfidence in anything that appears like "truth producing" or "a nature of proof."

The advocates of the overuse of the laboratory or the "process people" seem to think that if one can learn how to learn he can learn anything. This is a statement with which there must be universal agreement. The only problem is that no one knows how to learn everything. The "learn how to learn" people seem to be compelled to believe that knowledge is intuitive and of a single

species type. The argument in intuitive vs. discursive knowledge has been around since the time of Kant with the predominance of evidence to support the idea of discursive knowledge.

Further, who is responsible for so many teachers of science being convinced that scientists observe at random, that they form hypotheses in an algorithmic manner, that scientific knowledge is discovered, and so on? I beg to speculate that these ideas are spawned by individuals masquerading as science educators who are really educationists or educational psychologists using science teaching to their own advantage. These ideas can only come as a result of the overindulgence of the three groups for each other--educationists and educational psychologists, science educators, and scientists.

It is not a desire to see a resumption of the feuding of the many disciplines; however, it is time the people in the scientific community aid the teaching of science by alerting the general educationists that what is being said about *the structure* of science is generally not proper. It must be said that there is not "one structure of science." There are as many structures of science as there are knowledge components of science. It must be said that each component of science evolves necessitating its own academic history; however, all of science follows some well-accepted self-imposed ethical rules.

The science educator must help the science teacher learn what little is known of the pedagogy of the disciplines. The science educator must study the components of the disciplines, form hypotheses relative to the pedagogy of the parts, and test these hypotheses for credibility. To do this the science educator needs the cooperation of the scientists and the science teachers in the classroom. It must be recognized that a science teacher need not be a scientist and a scientist need not be a teacher. It must also be recognized that to learn the many types of knowledge already existent in the scientific disciplines does not require that each be developed anew by each generation of learners. The science educator, in harmony with the teacher of the classroom, must determine how individual increments of knowledge may be learned. This could definitely demand a more sensible use for laboratory activities, demonstrations, pictures, speaking, and reading.

Where has science teaching been in the last 40-50 years? The many disciplines have gone from providing knowledge that is to serve in decision making related to personal-social living, to knowledge for the sake of big science and little science, to knowledge that is to serve in decision making related to personal-social living. It is unfortunate that only recently have science educators begun
1. to examine the structure and evolution of selected concepts and

laws from the several disciplines with the eye to developing specific pedagogies, and 2. to study the history and evolution of the practices in science to the extent that the limitations and functions of science are coming to be known. Some scientists have known 2. for a long time but apparently have been reluctant to say something. Maybe more important is the fact that some of the vocal holders of the Ph.D. in a science discipline are really not scientists at all but rather are high class technicians utilizing the prestige of their academic society. As this is being written a recollection is fleeting among my thoughts of a comment made by a noted biochemist in about 1941 while speaking at a national meeting of science teachers. This is not precise but his general ideas were: The practice of science may produce great and important products of knowledge and products of great use for improving the living of people; however, it has its limitations. We are presently requesting the study of science to produce good, honest, moral, ethical citizens that never make decisions without *all* the information, who solve *all* their problems using "the scientific method," and who are interested in the conservation of the environment and welfare of fellow men. Although some of these may occur within people who study science or are scientists, they are not all proper to science or the consequence of the study of science. The purposes of science are to make the real universe of matter and energy understandable through the development of empirical and theoretical laws useful in explanation and prediction.

REDIRECTIONS FOR SCIENCE EDUCATION

It may now be proper to look ahead to what would be more productive in science education. The look back has had only one product--we have not accomplished much. How should a science educator be educated?

1. There is serious need for the scientists of this world to become informed of the philosophic structures of the disciplines they pursue. The Ph.D. is a doctor of philosophy, yet many who possess such degrees have no acquaintance with the philosophies or ethics that have produced the disciplines they dearly treasure. This is important because the science educators they teach and the teachers they teach tend to emulate the scholars or to use what they learn from such scholars to teach others. Thus science is presently often misrepresented. The epistemology of science is lost. The vocabulary that is precisely formulated is lost because the users do not know its proper function.

The science educator needs to spend more time studying the individual disciplines under or with true scholars of the disciplines, those who know the structures of specific concepts and laws and how the concepts and laws evolve.

2. There is serious need in science education for scholars concerned with the pedagogies of the elements of the disciplines of science. It seems that science educators have not found and will continue not to find much help from curriculum experts. The past supports the opinion that so-called curriculum theory is a fine "fun thing" to talk about; however, there really is no such thing. Curriculum in science refers to science. There can be no science curriculum without science. It is hollow to talk about curriculum devoid of content. Yes, the educationists will not like such talk because they say "the curriculum theorists help to direct the nature of the learning provided in the schools." To this I must reply that their effect is not significant. To know how to plan curricula one must know the potentials of the elements that make up those curricula. The benefits that may be derived from the study of science can not be known without knowledge of science itself. The potential of science is just as limited as that of other disciplines.

The pedagogies of the disciplines are not singular because each discipline consists of many species of concepts, many types of laws, and many procedures of evolution. The concepts and laws vary from descriptive to quantitative. The level of mastery desired for the pupils varies from recognition to application. How, then, can anyone really believe in "*a* structure of teaching." Needed are precise structures for helping pupils to learn a given concept or law with its sophistication defined to a specific level of mastery. There are many structures of teaching rather than one structure needed.

Along with this more precise knowledge of the components of a given learning outcome will come the ability to more effectively assess mastery. The area of interest known as science education must develop a subset: measurement of achievement in science education. The content of science is unique, hence the measurement of achievement in science knowledge is unique. We should divorce ourselves from the traditional test construction experts from educational psychology. Realize if you will that there have been no significant breakthroughs in test construction since the introduction of objective tests before 1920.

3. Every science educator should be aware that educational psychologists have contributed little or nothing to improve the teaching of science. How much more is there than this?

- The maturity of the learner is a factor in learning.
- A learning sequence should proceed from simple to complex.
- A learning sequence should proceed from the concrete to the abstract.
- A learner learns best and most efficiently when he identifies that which is to be learned with himself and his values.

Note that these are really only commonsense statements.

The developmental psychologists have been of some assistance by collecting evidence that enables educators to interpret behavior patterns in terms of norms and deviations from norms. Science educators may benefit from some knowledge of the mental and physical developmental patterns of learners.

4. The science educator should carry out detailed study of the philosophies of science: Carl Hempel, Karl Popper, Leonard Nash, Ernest Nagel, Philipp Frank, Rudolph Carnap, Immanual Kant, Sylvain Bromberger, John Kemeny, William Beveredge, Israel Scheffler, Wesley Salmon, and others.

The philosophies of science may lead the science educators of the future to form an epistemology that will enable them to dispose gracefully of such terms as *inquiry teaching, discovery, scientific attitude,* and so forth, to come to realize that there are no known algorithms for hypotheses and theory formation, to find that science has many limitations in terms of the benefits contributed to those who study it, to learn that the proper function of scientific concepts is that of enabling communication and the formulation of laws describing real or proposed uniformities in natural phenomena, and to understand that the procedures allowed by the ethics of science lead only to an understandable universe.

Thus it may be said that the science educator must work more closely with the scientist than with those in educational sociology and educational psychology because the well-informed doctor of philosophy in a science discipline can help develop a sound series of empirical pedagogies related to the specifics to be learned.

It is futile to regret to have but one life to devote, however it is dishonest to keep to yourself the inadequacies of the present system. It is essential that the community of scientists embark upon a campaign to redirect the teaching of science. They must not permit the dissemination of erroneous beliefs about the personal benefit derived from the study of science, how scientific knowledge comes into being, and how it evolves. A self corrective mechanism must be structured into science education if the same errors are not to be consistently recycled.

REFERENCE

1. National Society for the Study of Education. Committee on the Teaching of Science. *A Program for Teaching Science.* Thirty-First Yearbook, Part I. Chicago: University of Chicago Press, 1932.

T. R. Porter was born in Nebraska in 1912. After completion of his elementary and secondary education in South Dakota schools he attended the University of Nebraska from which he received his A.B. in 1934 and his M.A. in 1936. His Ph.D. was awarded from the University of California-Berkeley in 1941. He did post-doctoral work at the Pennsylvania State University during 1950-1951.

Dr. Porter served as a laboratory instructor in botany while completing his M.A., after which he held a similar position until 1938 at the University of California. From 1938 until 1953 he was a faculty member of the Department of Biology at City College of San Francisco. In 1953 he went to Pennsylvania State University as an Assistant Professor. He was promoted to Associate Professor in 1956 and served as Coordinator of the Science Teaching Improvement Program. In 1957 he moved to the University of Iowa as Associate Professor and Head of Science Education. From 1965 until his retirement in 1968 Dr. Porter was a Professor and Head of Science Education. After his retirement from the University of Iowa he joined the Department of Biology at Sonoma State College in California. He retired from Sonoma State College in 1977 as Professor Emeritus.

Dr. Porter has been an active participant in professional organizations including NARST, NSTA, CASMT, AAAS, Iowa Academy of Science, Iowa Science Teachers Association, and the Iowa Conservation Council. He was elected a fellow of the AAAS and of the Iowa Academy of Science and served as vice-president of the CASMT in 1960. He served as president of the Iowa Conservation Council in 1965.

In addition to his teaching duties Dr. Porter served as director of the Conservation Education Laboratory for Teachers at Pennsylvania State University. He also directed the NSF sponsored Iowa Visiting Scientist Program between 1960 and 1967 and directed numerous NSF institutes for teachers. He served as Iowa Director of the U.S. Army Science and Humanities Symposium and later as West Coast Director of the Junior Science and Humanities Symposium.

Dr. Porter researched and published actively during his career including 20 research papers and articles. The series of three NSTA publications on Teaching Tips from TST which he compiled have been widely used.

Dr. Porter's service and scholarship have been recognized. He was awarded a post-doctoral fellowship to Pennsylvania State University during 1950-1951. The U.S. Army presented Dr. Porter with an Outstanding Civilian Award in 1966.

REFLECTIONS ON THE CHANGES WHICH HAVE OCCURRED IN SCIENCE EDUCATION IN THE PAST TWENTY-FIVE YEARS

T. R. PORTER

Biology Department
Sonoma State College
Rohnert Park, California

In 1953 I decided to abandon "true science" to enter the field of "science education." At that time there was a great difference in these two areas, at least in the minds of some people. Science education had the attached stigma of only teaching teachers how to teach with little or no consideration given to their academic background. No doubt this kind of program may have existed in some teacher education institutions but there were several bright spots where both a solid academic background as well as educational theory and actual, carefully supervised classroom teaching experience were required. Fortunately, the philosophy behind these well-balanced teacher education programs has been adopted today by the majority of the science teacher education programs.

Twenty-four years ago, and even earlier, there existed excellent science teaching in many schools at both the elementary and secondary levels. But, generally, this was not universal. Nor was there much opportunity for teachers to be brought up to date; there was less opportunity for the many teachers with little or no science background to go back to school and obtain the necessary information so they would be knowledgeable and secure in teaching the more sophisticated science they were required to do. As a result in many schools any kind of an organized, continuous, coordinated science program, kindergarten through grade 12, did not exist or was not used if a course of study was available.

At the elementary school level true scientific programs were spotty. A number of individual schools and/or school districts had prepared good courses of study for the elementary grades. Some states already had up-to-date courses of study and in others efforts were being made to revise and update the science programs. In many instances there was a K-12 coordination, in other cases this continuity was not considered. As a result there was subject matter repetition to the extent that it turned off the students' science interest--permanently in many cases.

Some surveys were made to determine the use made by the classroom teacher of the prepared courses of study. It was found that in some instances only one-third use was made of these prepared programs; in other situations the course of study was not even available. This is not to say that there was little excellent science instruction in many schools but it does say there was no national awareness of the need to do something about science instruction K-12. Many courses at the college and university levels needed to be evaluated, too. Now many of the science courses offered at the college and university level have been evaluated and changes made which consider the incoming students' background as well as the new scientific research and discoveries.

CHANGE IN ATTITUDE TOWARD SCIENCE EDUCATION

There were probably two events responsible for the change in attitude on the part of schools and the general public. The first event which really had an impact on school administrators, teachers, parents, and the general public was the launching of sputnik. This advanced science education at least 10 years. Everyone was concerned that the United States was slipping from the top of the heap and the science programs came under careful scrutiny. Many school administrators were ready to scrap their school's entire science program. Physics, where enrollment had dropped to an all-time low, was now looked upon in a different light. Mathematics also became more important; instead of being scrapped it even became an important part of the physics course again.

The second event which had a long-range impact was the initiation of the Physical Science Study Committee (PSSC) curriculum development at the Massachusetts Institute of Technology (MIT) in 1956. This sent shock waves through special groups--high school science teachers (especially those teaching physics) and some college physics faculties. These shock waves increased in scope as this program spread to different schools. It also had an impact on those people writing high school physics textbooks. They not only reorganized the content but modernized it.

Fortunately, today the general attitude and information concerning science and science teaching have changed. Rarely does one hear the question "What's that?" when the phrase *science education* is used. Nor do parents raise the question as to why elementary and secondary teachers need special help in science--not only content-wise but also to be informed of the many different ways a topic can be presented to the students. The general public (and especially parents of elementary school age children) know that children in this age bracket are capable of understanding science and are interested and receptive to it.

In the early 1950s organization of the National Science Foundation (NSF) was just under way. The foundation had a very small budget and a congressional mandate to initiate and support programs to strengthen science education at all levels. At first there was some question as to the best way to proceed. There seemed to be a feeling by some people that the emphasis should be to encourage scientific research only--certainly an important aspect. Others interpreted the congressional mandate to include the strengthening of science teacher training and science course improvement programs such as PSSC physics. Fortunately, a farsighted interpretation gave the foundation's services a broad base. Certainly basic research was essential to the development and survival of our country but for this to continue the future generations of potential scientific researchers must be provided with the opportunity for a solid up-to-date background. NSF's impact on course improvement and science teaching is without question. Its grants for in-service, summer, and academic-year programs for teachers provided the incentive--both psychologically and monetarily--for many teachers to go back to school and be brought up to date on the latest scientific research and teaching methods. Some of these teachers have continued their education and are now research scientists. Thus, both goals of NSF have been attained.

As mentioned earlier, the first "experimental" science program, that of PSSC organized or founded in 1956 at MIT aimed to develop an improved introductory course in high school physics--something which was badly needed. This program was sponsored not only by NSF but by the Ford Foundation and the Sloan Foundation. The impact of this program was much broader than just to improve the teaching of physics. It served as the model and catalyst for evaluating and restructuring programs in biology, chemistry, and earth science at the high school level. Its impact was also felt at the junior high school and even the elementary school levels. As science curriculum improvement projects in the other sciences were developed, taught in pilot schools, improved, and expanded to the junior high and elementary schools, a true renaissance in science education was at hand. The impact of these programs has been felt at the college and university levels. The impact has even been reflected in many of the longtime used so-called traditional science texts at all levels. Many exciting and instructive visual aids have been developed and much thought and research has been devoted to the evaluation of these new approaches to science teaching. As a result many changes have taken place in the past years in both the teaching approaches and content.

A probable spin-off from all of this change has been the continued, but increased, interest and concern about the environment. An increasing percentage of the population was becoming concerned and frightened about what we were doing to our environment but little was being done to correct the situation. Thus, the time was

213

ripe for another catalyst like sputnik. This came in the form of gasoline rationing and price increases. Again the direction, interest, and concern have been modified, and for the good of mankind. Science is still playing a most important part in this great concern about our environment. To understand and determine environmental impacts, a broad science background is essential. If anything, there is now the opportunity for down-to-earth, everyday applications of science; not only to understand the reason for the concern about our natural resources but to be able to judge whether the so-called environmentalists are accurate and reasonable in their evaluations.

FUTURE EMPHASES IN SCIENCE EDUCATION

What should be done to keep pace with future developments in science? Certainly greater emphasis on in-service, summer, and academic year programs. This accompanied by more stringent requirements for the teachers to attend one or more of these special programs within a given time frame. It would be hoped that this would direct the teaching philosophy to a teacher-directed, rather than a teacher-dominated, learning situation. The result would be greater direct involvement of the students in the experimental and research approach to learning. Even kindergartners are capable of simple research projects which may be overlooked as such by adults. This often happens because these simple projects at the kindergarten level seem so simple, but to the young child these science activities may be as difficult and intriguing as Louis Pasteur's experiments were to him.

In connection with teaching biology at any grade level--where possible and practical--more time should be spent in the field. Thus, the students have the opportunity to make firsthand observations and record data. Too often biology has been taught with dead materials which means that the students really don't see life in action. Field work also presents the opportunity for students and teacher to develop a differ kind of relationship and often this makes the learning process much more viable.

Another necessity on a continuing basis will be to evaluate carefully the individual science courses as well as the entire science program. The appropriate and timely topics, or courses, should be retained and new information added to keep pace with the times.

In the years to come it is hoped there will be as much new information, research, and development as in the past 10 or 15 years. Doubtlessly there will be terms used that would be completely strange to us today. The younger scientists probably will

be speaking a language that will not be understood by many of today's scientists--unless they keep abreast of the research being published. For this reason it is so essential that included in the teacher education requirements of the years to come will be an emphasis on the new information and concepts based on the current research of the times.

Much of the science fiction of today may be the science of tomorrow. For this reason as well as those mentioned before, the science programs at all grade levels must emphasize the way a scientist does research as well as what he has learned. Now that science has become an important and universally accepted part of the curriculum it is essential that those responsible for curriculum development, teacher education, in-service programs, and action research will continue to maintain, or even elevate, the various aspects of science education.

215

Fred R. Schlessinger was born in 1907 in Colorado. After his elementary and secondary education in Colorado schools he attended Colorado State College of Education at Greeley (now the University of Northern Colorado), from which he received his B.A. degree in 1934 and his M.A. degree in 1941. His Ph.D. degree was awarded from The Ohio State University in 1957.

Dr. Schlessinger taught in Colorado elementary and secondary schools for fifteen years, from 1929 until 1944. He taught in elementary schools until 1935 and was a secondary science teacher from 1935 until 1944. He served in the United States Navy from 1944 until 1946. In 1946 he joined the faculty of Edinboro State Teachers College as an instructor. He was named Assistant Professor in 1951, Associate Professor in 1954, and Professor in 1958. In 1959 Dr. Schlessinger joined the College of Education of The Ohio State University as an Associate Professor of Science Education. He was promoted to Professor in 1963. Dr. Schlessinger remained at OSU until his retirement in 1972. He currently holds the rank of Emeritus Professor of Science Education.

Dr. Schlessinger was an active member in numerous organizations including NSTA, NARST, AETS, AAAS, NSSE, NEA, throughout his career. In addition to various committee responsibilities he served as regional director of AETS in 1963. Dr. Schlessinger also directed the NSTA 1961-1962 facilities study.

Besides his regular duties in science education at OSU, Dr. Schlessinger also directed numerous NSF summer, inservice, and academic year institutes between 1968 and 1971. In 1965 he served as coordinator of 33 summer science and mathematics institutes for college and university teachers in India as part of a U.S. AID project.

Dr. Schlessinger has published articles in science education and education journals. He served as editor of the second edition of the Science Facilities for Our Schools K-12 published in 1963. Dr. Schlessinger was major coauthor of a summary report of a national survey of secondary school enrollments. He also provided editorial services for School Science & Mathematics and The Science Teacher.

Dr. Schlessinger's scholarship and service have been recognized. He was awarded a senior biology scholarship, the Pessman Award, while at Colorado State College of Education. He was also elected to a number of education and science honoraries including Phi Delta Kappa, Kappa Delta Pi, and Alpha Psi Omega. While teaching at Edinboro, Pennsylvania, he was cosponsor of the chapters of Beta Beta Beta, Kappa Delta Pi, and Alpha Psi Omega.

THE IMPACT OF INSTITUTES
ON SCIENCE TEACHER EDUCATION

FRED R. SCHLESSINGER

Emeritus Professor
The Ohio State University
Columbus, Ohio

In the bicentennial year as the nation recalls the history of our social and political achievements, those of us who have been involved in science education reflect on the origins and development of science teaching in our secondary schools. We recall that the early academies often included some natural and physical science courses in the curricula. When the English grammar school first appeared some science was offered. As the public high school developed over the century a variety of science courses came into existence. Some of the course titles remain to the present while other courses gradually faded away.

By the middle years of the twentieth century the most common science courses in secondary schools included general science, biology, chemistry, and physics. In the early part of the 1950s leaders in education and industry were concerned about the lack of student interest in science and mathematics. There was also great concern about the small number of talented students going on to higher education (3). Leaders in both industry and government pointed out the related problem of a lack of scientific and technological manpower. A number of writers pointed out the comparative figures of the numbers of graduating engineers and scientists coming from American and Russian colleges and universities. John T. Rettaliata reported that

> From 1951 to 1954, inclusive, the universities and colleges of this country graduated some 116,000 engineers. In Russia, the reported total for the same years was 154,000 (2).

These concerns led to a study of the lack of motivation of high school graduates to attend college. The conclusion was that the quality of instruction and guidance in our high schools needed to be improved. The assumption was made that the cause of this low motivation was due in part to the type of science and mathematics instruction existing in the secondary schools. It was also

discovered that many capable high school teachers had left teaching for higher paying jobs in industry. A study of "Teachers! Salaries" showed that the average income of the teachers was about 10 percent lower than that of the national labor force in the years 1954 and 1955 (5).

A study of high school science teachers showed that

> In 1954, 5700 new science and mathematics teachers were employed. . . . Of these 2300 were new college graduates. Of the 3400 others, some were with excellent preparation returning to teaching after varying lengths of absence. But others of the 3400 were hired simply because no better qualified candidates were available (6).

THE BEGINNING OF INSTITUTES

A number of programs for science and mathematics teachers had been established by the middle of the 1950s. Most of the early programs took the form of summer institutes. Stated objectives of these programs usually began with an intended raising of the subject matter competence of the teachers. In 1956 six industries and two private foundations had established summer programs for science and mathematics teachers. Some of the leading colleges and universities were involved with the institutes.

In 1950 an act of Congress established the National Science Foundation (NSF). The purpose of this legislation was to develop and encourage the pursuit of a national policy for the promotion of basic research and education in the sciences. Under a broad interpretation of the charge placed on it by Congress, the foundation established a number of summer institutes. The planners stated that the institutes should be designed to help high-school and college teachers of science increase their subject-matter competence (1)."

The growth of summer institutes was phenomenal. NSF established the first two in 1953 and by 1957 they were supporting 95 institutes at various colleges and universities across the country. Growth in the number of these institutes continued for several years but at a slower pace. At the same time a number of the earlier sponsors of institutes gave up the field to the NSF programs.

The colleges and universities that were granted support for institutes developed many new courses especially for teachers, frequently assigning their best professors to teach these courses. Emphasis was placed on presenting the most recent developments in the various academic fields. To some extent an effort was made to

show the interrelatedness of the various scientific disciplines. Only minor attention was given to teaching techniques except through example.

NSF was interested in other means of improving science and mathematics teaching in secondary schools. A number of curriculum programs were developed starting with the Physical Science Study (PSSC). Summer institutes and workshops were developed and funded for the specific purpose of acquainting high school teachers with the specific curriculum materials of their teaching fields. Such programs were reasonably successful in updating the curriculum in science and mathematics in a large number of schools.

Other innovations in science teacher education have been developed over the years. Some of these include the sequential summer institutes, the school-college cooperative programs, and of course the academic year institutes. The various programs often increased in importance only later to be modified or phased out. All the programs have had an effect on science teacher education.

THE ACADEMIC YEAR INSTITUTE

The Academic Year Institute (AYI) was developed for the purpose of giving outstanding young teachers an opportunity for a concentrated year of study. The numbers of these institutes in major colleges and universities increased during the 1960s. Late in that decade a change in support by NSF made it impossible for many colleges and universities to continue operating the academic year programs. The number of science and mathematics teachers reached by this program was substantial but in terms of total number for all types of programs it was rather a modest undertaking.

Some of the outcomes of the AYIs were not intended. However the long-term effect of these institutes may be greater than all the other programs combined. NSF intended for the participants in the programs to return to the secondary schools and become leaders in their teaching fields. Many teachers did return to the public and private school systems where they are doing outstanding work, some in the classroom while others have become supervisors. However, a substantial number of the participants in AYIs remained at the college or university long enough to obtain an advanced degree. Many of those who completed the doctoral program may now be found in universities and colleges all over the country. They are usually working in some phase of science or mathematics teacher education.

219

LOOKING BACK

After nearly 20 years of institutes it seemed important to take a look at their impact on science teachers and on science teacher education. A survey of science teaching in public schools of the United States was made in 1971 by a team of researchers (4:98-100). The survey was perhaps the most comprehensive study ever made of the conditions of science teaching in this country. It should serve as a bench mark of data for future studies of science teaching.

Of the many findings resulting from the study the effects of institutes on the teachers and on the curriculum seem noteworthy. Even after the loss of secondary school teachers to the colleges and universities 9.2 percent of the science teachers remaining in public schools had participated in an AYI. This did not include former teachers who because of their institute training had remained in the public schools but had taken on administrative positions. Over 50 percent of the science teachers in the study had participated in at least one summer institute. Because of sequential institutes and other liberal rules many teachers had gone to several summer programs.

Institutes and workshops were commonly provided for teachers who were adopting a specific science course improvement project. Of the teachers responding to the study it was found that 53.9 percent had attended such a workshop or institute. At the time of the survey, 1971, it was found that 71.7 percent of the teachers had not participated in a NSF sponsored Inservice Institute (ISI). Since the survey was conducted much greater emphasis has been placed on the school-college cooperative programs. Thus the figures for in-service work will have changed.

LOOKING FORWARD

The science education departments in many colleges and universities have from one to several former institute participants on their staff. To a large extent these staff members have shown their creativeness by developing a variety of innovative science teacher education programs. Whether an assumption can be made that their experiences in institutes are responsible for their inventiveness is not important. What is important is that constructive changes are taking place and will continue so long as we can have such highly motivated teachers interested in science teacher education.

220

REFERENCES

1. Northrop, E. P. "Efforts to Strengthen Science." *Science*. 122(September 16, 1955):505.

2. Rettaliata, John T. "The Scientific Manpower Shortage--A Peril to America." *School and Society*. 82(July 1955):17.

3. Rickover, H. G. "The Situation in American Engineering and Scientific Education." *School and Society*. 83(May 26, 1956):1976.

4. Schlessinger, F. R., and others. *A Survey of Science Teaching in Public Schools of the United States* (1971). Vol. 1 of *Secondary Schools*. Columbus, Ohio: ERIC Information Analysis Center for Science, Mathematics, and Environmental Education, 1973.

5. "Teachers' Salaries." *School Life*. 38(March 1956):10.

6. Wolfle, Dael. "High School Science Teachers." *Science*. 122(September 2, 1955):399.

221

Herbert A. Smith was born in Nebraska in 1916. Almost all of his formal education was in Nebraska schools. After graduation from high school he attended the University of Nebraska from which he was awarded all of his higher education degrees: his B.S. in 1938, his M.A. in 1941, and his Ph.D. in 1948.

Dr. Smith held secondary science teaching and administrative positions in Nebraska schools from 1938 until 1944 when he entered the United States Navy. After leaving the Navy in 1946, he joined the University of Nebraska faculty as a part-time instructor in science education. He was promoted to Assistant Professor in 1948 and to Associate Professor in 1951. In 1953 Dr. Smith joined the faculty of the University of Kansas as an Associate Professor and Director of the Bureau of Educational Research and Service. He was promoted to Professor in 1955. Dr. Smith remained at the University of Kansas until 1962. He was a summer visiting Professor to the University of Maine in 1962. From 1962 until 1964 he served as Professor and Head of the Department of Secondary Education at the Pennsylvania State University. After having spent the summer of 1963 as visiting Professor at the University of Colorado, Dr. Smith returned to the state in 1964 as Director of Teacher Education and Head of the Department of Education at Colorado State University. He has held various administrative positions from Associate Director of Education to Assistant to the Academic Vice President at Colorado State University.

Dr Smith has been an active member of numerous professional organizations including NARST, NSTA, AETS, AAAS, NEA, and the Colorado Education Association. He was elected a fellow of the AAAS and has held a number of positions in the Education Section of AAAS. Dr. Smith served as president of NSTA in 1958-1959, of NARST in 1961, and of AETS in 1964. He has also been an active member and officer in the Association of Deans and Directors of Colleges of Education of State Universities and Land Grant Colleges, holding the presidency in 1969.

In addition to his administrative duties Dr. Smith has served as a consultant to the U.S. Office of Education and to science film, encyclopedia, and supply companies. He also served on a U.S. AID mission to Thailand in 1971. Dr. Smith has actively researched and published throughout his career. He has authored a biological science textbook and coauthored an elementary science series.

Dr. Smith's scholastic ability was recognized with two scholarships while attending the University of Nebraska. His service to science education was recognized by NARST in 1962 with a Distinguished Service Citation.

RETROSPECTIVE ANALYSIS AND ASSOCIATED PROFESSIONAL POTPOURRI ON THE STATE OF SCIENCE EDUCATION

HERBERT A. SMITH

Assistant to Academic Vice President
Colorado State University
Ft. Collins, Colorado

It should not be too much of a surprise if a survivor of the Dust Bowl of the thirties and the Great Depression which accompanied it and one who later survived nearly two years of active duty in military service in the Southwest and Western Pacific theatre during World War II should look with a somewhat jaundiced eye on the world which affluence has produced. Since others are more likely to write in the tradition of a bigger and better America and the great progress which they perceive to have been made in science education, it is perhaps not entirely inappropriate to take an alternative point of view and to examine whether or not the progress made in the last four decades may be more illusion than fact.

THE AMBIENT CULTURE

The winds of change have swept over my generation with tornadic intensity and have left the debris of shattered life styles, customs, and values in their wake. There have been great social upheavals in the past, but it is doubtful that even the crumbling of the Roman Empire before the barbarian avalanche, the depredations of Tamerlane in his immense operations from the Mediterranean to China, or the Red Revolution had any more fundamental effect on the life styles for those who were lucky enough to survive than the social and technological revolution produced in this country in the last half century. The raising to a high state of technological efficiency of devices for communication and transportation as exemplified in the radio, television, the automobile, and the jet airplane, accompanied by equal technological proficiency in the production of food and of most other consumer goods, has created absolutely unique social conditions; conditions which we are not yet able to accommodate either politically, economically, or socially. The current chaos in these areas at city, state, and national levels only too clearly testifies to the accuracy of this assessment.

The schools have been caught in the maelstrom of change and the social disintegration which has accompanied it. They have often been the targets of unjustified criticism and the victims of the propaganda technique of scapegoatism. The schools cannot rise above the society which sustains them and they will reflect to a greater or lesser degree the same ills that are found in the larger society. To expect children to be disciplined at school when they are not disciplined at home, to demonstrate sound work habits and energetic application to assigned tasks at school when they are required to do nothing at home--when they are overindulged, neglected, with too much money, too much "empty" time, and with too little guidance outside of school--is to expect that which is highly unlikely. For the schools to produce model students would indeed require a miraculous transformation.

The real crisis of our time is a crisis in values. The concept of value is an exceedingly complex one. However, it might be instructive to consider a few aspects of this thorny subject. Subjectivity is inherent in all values and it is impossible to separate the individual valuer from the evaluated. I have a pet dachshund of which I am very fond. Although it is a simple one, Fritz has a value system of his own and unlike numerous collegiate undergraduates and a sprinkling of faculty he is certainly not confused about what values he holds. He indicates a decided preference for a nice soft rug rather than the bare floor to sleep upon and he prefers warmth to cold and dryness rather than wetness. He certainly prefers meat scraps to his perennial dry dog food. Fritz gives us a picture of valuing as a matter of choice, a choice among alternatives. His behavior also reflects that values are the bases and the determinants of behavior. But as fond as I am of Fritz, his valuing system has some severe limitations as viewed from my perspective. There should be a notable difference between Fritz's determination of values and the human approach. Fritz is a "now" creature. For him the present is all there is; he reminisces on no yesterdays nor anticipates any tomorrows. The consideration of the consequences of choices and the adding of a time dimension are characteristically human modes of behavior and beyond Fritz's capabilities. If we think of this observation in terms of the long evolutionary development of man, perhaps this characteristic may have been the critical difference which gave rise to civilization. The domestication of plants and animals was a critical factor in laying the basis for civilization and permitted man's rise above the level of savagery. Because he could anticipate consequences man learned to conserve his breeding stock and to save seed for planting another crop.

What are the implications of such an observation applied to the current generation which has been described as the "now" generation? It is precisely because man outgrew the "now" concept that he is man and a civilized being. He was able to weigh antecedent and consequent. He was able to defer the immediate for a larger,

later benefit. What connotations does this kind of thinking have for the permissive society in which we are engulfed? "Do your own thing" is a standard cliché and an aberrant notion of freedom intellectually supported by Sarte, Camus, and Marcel brands of existentialism runs rampant. The test of the desirability of an act seems to be the amount of immediate gratification it will yield. It is divorced from time and consequent. Justification for such ultimate egocentricity finds intellectual support in existential dogma which "...can hold that human existence projects itself with absolute freedom, itself by itself, thus assuming to itself the function of God (3). But if we are to embrace such doctrine then we are reverting more to an animal level of behavior and leaving our humanness behind. We are operating at Fritz's level of valuing. Such philosophy, of course, is not new. It is probably as old as man and Louis XV's famous *aprés nous le deluge* is a classic illustration from history. In literature we find another perfect example from the *Rubá iyát*

Some for the glories of this world;
And some sign for the Prophet's Paradise to come;
Ah, take the cash, and let the credit go;
Nor heed the rumble of a distant drum (12).

It is only the extent to which the Sarte, Camus, and Marcel types of existentialism have been implemented and practiced which is new and which, at least from the perspective of the writer, is the tragedy of our time. It is basic to both communist and such existential doctrine that the end justifies the means. "Doing your own thing" is the *au courant* philosophy and mirrors Marcel's dictum that everything beyond the individual is a minus sign. Although it is extolled as a liberating and humane development it is actually quite the contrary. Pushed to its logical consequences it is the most amoral, self-centered, and self-seeking doctrine that can be imagined. Clare Booth Luce has recently written of the insidious affect on today's youth generation of such philosophical nihilism. She states:

> The rise in this decade in juvenile muggings, armed robberies, rapes, car thefts, prostitution, drug peddling, drug-taking, and alcoholism is horrifying. In the most affluent society on earth, more than five billion a year are purloined by youthful shoplifters. Youthful vandal'm costs our society another several billion annually. . . . The parents, teachers and professors of today's young rebels were in their cradles when the intellectuals proclaimed "the death of God," the "Old Man" of the entire Judeo-Christian tribe and began to scrap the moral standards by which Western society had judged right and wrong, good and bad, desirable and undesirable human conduct for centuries. The parents, naturally enough, became

"permissive." But their children were also in their cradles when--in the sacred name of free speech--the liberal intellectuals defended in the Supreme Court the right of publishers, play and film producers to flood America with filth. The merchants of porn, grue, perversion and violence became millionaires. The kids who were nurtured on them are today's hop-heads and alcoholics, fire-bomb throwers and thrill-killers (6).

The anarchy in values is reflected on the educational scene in many other ways; the attack on grading practices and standards in general, the attack on properly constituted and exercised authority, the demand for relevance (along with the "obvious" corollary that students could, of course, determine for themselves what was relevant), the student involvement movement, and the vigorous attack made on rules, regulations, and procedures are all indicative of the crumbling walls of established values.

Two other aspects of values which seem worthy of mention at this point are the common acceptance of the ideas that one value is as good as another and that any individual has a right to hold any values he desires. Both of these positions seem transparently false but they are seldom challenged and they are capable of immense harm. Values are important because they give direction and consistency to behavior. Man is a social animal and he lives in a social world and, therefore, his behavior has social consequences. It is not possible to be oblivious to these consequences. We are fundamentally and ultimately concerned with the values which people hold because of the impact of values on individual and social behavior and on social interaction. If this be true then some values have more social utility than others and individual man cannot unilaterally determine for himself what values he will hold. A democratic society cannot long endure value anarchy for values are the social cement which makes productive social intercourse a possibility. John P. Wynne has made a thoughtful analysis of the theory of free choice which is highly apropos in the context of this discussion (15).

This then is a vignette of the kind of social milieu in which schools and science teachers must operate. And it is the milieu which creates many of the problems with which schools must contend and for which schools are often erroneously blamed.

BIG TIME SCIENCE

Since the Great Depression science has certainly prospered, but it has been an uneasy prosperity fostered by wars, both hot and cold, and by international struggles for technological supremacy and national prestige. Federal agencies with science oriented missions

226

have proliferated. In this period one of the great educational landmarks has been the National Defense Education Act (NDEA) which was passed for compelling political reasons rather than for professional ones. The period has seen the flowering of the concept of categorical legislation and the rapid politicization of science.

Science, particularly high energy physics, and the technology of war and space became immensely costly. Science, and especially physics, as the premier discipline of our times became big business. One need only look at the buildings erected on campuses across the nation in the last two decades to see the physical manifestations of the support for science and the impact of the mechanism of categorical aid. Although it seems probable that support for science and related activities has now passed its peak and that we may be returning to a period of a more "normal" level of support, the impact of the tremendous categorical financial support for science of the last 25 years will be felt for decades.

But science has not enjoyed the fruits of tremendous economic support without paying a price. One does not have to look far to find critics who assert that science has prostituted itself in the interests of war and war technology. But perhaps the more insidious effects are less obvious. The use of the device of categorical aid for science and other preferred programs has created a host of problems. It has created a status hierarchy of haves and have-nots on many campuses with glaring inequities in facilities, salaries, and expense budgets. The requirement of matching money for the federal dollar has frequently resulted in draining needed funds from other needed but not federally supportable programs to support programs or facilities which were already heavily subsidized.

On the professional side, a generation of "grantsmanship" scientists has developed. Research proposals are drafted today with an eye toward the climate in Washington and what is most likely to be funded. The historic procedure in which a brilliant new insight was conceived which needed to be explored, with money then being sought to test the validity of hypotheses drawn from it, is now more or less passé. The long-range implications of such a trend is that the direction of research and development is politically, rather than professionaly, determined. The political intrusion into genetics exemplified by the Lysenko affair is a classic example of the sterility resulting from political intervention in a professional area. Furthermore, graduate students find that typically their freedom in selecting research problems is restricted to problems related to funded projects in which their advisor is the major investigator. In some cases the thesis problem is already fully defined and handed to them.

Whether graduate students are being exploited in such a system is moot but it might certainly be argued that one of the purposes of graduate study and research is the development of skills and insights sufficient to identify, define, and explore an appropriate problem and that to deprive students of the opportunity short-changes them in part of their education and often reduces them to technicians' roles. Unfortunately what has been said above also applied to science education and education in general although to a lesser degree.

The encroachment of the federal government on education at all levels is a serious and growing problem. The judicial and legislative determination of educational policy is a dangerous trend. Controls are exercised through the legislative processes including categorical aid and the bureaucratic rules-making authority of federal agencies. The regulations are enforced generally through the threat of withholding of federal funds and more occasionally through recourse to the federal courts. The intrusion of the federal government in such diverse matters as the busing issue, civil liberties, student discipline, and affirmative action along with special interest legislation are examples of federal intervention in the educational process. It appears as an interesting and ironic fact that former secretary of Health, Education and Welfare, David Matthews, while he was president at the University of Alabama, made the following damning statement about external regulation. He stated that such regulation threatened to:

> . . . bind the body of higher education in a Lilliputian nightmare of forms and formulas. The constraints emanate from various accrediting agencies, federal bureaucracies, and state boards, but their effects are the same: a diminishing sense of able leadership on the campuses, a loss of institutional autonomy, and a serious threat to diversity, creativity and reform. Most seriously, that injection of more regulation may work against the accountability it seeks to foster, because it so dangerously diffuses responsibility (13).

The mechanism of categorical aid, the threat of the withholding of federal dollars, and the judicial system have been the primary weapons of federal intervention in educational policy, curricula, and operations. Thoughtful educators must question whether the old "carrot and donkey" metaphor used to describe government efforts to induce educational changes deemed necessary or desirable have not given away to a "mule and bullwhip" analogy in which the mule is forced down a path and in a direction determined by bureaucratic edict buttressed by legislative and judicial sanctions. Clearly a fundamental issue is the question of whether the contribution of federal dollars, often a small percentage of the institutional budget, should be able to mandate the manner and the method of

expending nonfederal dollars. To this writer, there should be no issue since the constitution does not provide for the control of education by the federal government. It is therefore an unwarranted usurpation of federal authority and an invasion of state and loc. rights to do so through the modality of federal fiscal, bureaucratic, and judicial intervention.

What most concerns me is the basis for the decisions made about education in federal agencies and my lack of confidence in the process. A short tour of duty (20 months as chief of the Science, Mathematics and Foreign Language Section) in the Office of Education (USOE) was extremely revealing as to the political vis-á-vis the professional nature of the decision-making process. Although I had served on active duty as a commissioned officer in both the Army and Navy and am a veteran of World War II, I was not prepared for the "chain of command" style characteristic of USOE. Where a professional orientation was expected, a much more militaristically oriented organization was discovered. In short, federal agencies do not exude a climate conducive to the best professinaal decisions; they are far too sensitive and, in all fairness, perhaps too exposed to the political winds which forever blow from the two ends of Pennsylvania Avenue.

In spite of the tremendous prestige which science has enjoyed in the recent past it has apparently failed to reach the thinking, and influence the behavior, of the large mass of people. It has not been particularly successful as a humanizing and broadening discipline. It is, indeed, a peculiar social anomaly that at the very time science and technology were achieving their greatest triumphs we should see a rise in the public interest in and involvement with various occult mysticisms, astrology, and self-proclaimed psychics. Numerous other examples of recourse to nonrational behavior ranging from a belief in ouija boards to damaging health practices including diet fads that have absolutely nothing to commend them and to drug addiction have become commonplace. It is a rather amazing fact that recently a group of 186 scientists, including 18 Nobel prize winners, felt that it was necessary to set forth their views invalidating the pretentions of astrology (10).

On another front, we do not seem to have been notably successful in persuading all Americans that natural resources are finite and we have not made notable progress in getting Americans to change their life styles to ways which are substantially less costly in terms of the energy inputs required. As a people we are not yet committed to the need for sound conservation practices. We are wasteful and prodigal in the use of materials and energy. We appear to be convinced that the road to Utopia leads always in the direction of higher and higher standards of living.

Science has been rightfully promoted as the hope for the future to provide food, fabric, shelter, and health care for the multitudes but the dark side of scientific achievement has not escaped attention and has produced concern and anxieties in the masses of people. The significance of the obliteration of Hiroshima was not lost. The atomic bomb was only another weapon of war made possible by scientific discovery and technological applications, but it was an "ultimate" weapon. For the first time the power to destroy the whole earth passed into the hands of men. Other less dramatic, but potentially equally destructive, developments include herbicides, nerve gases, human cloning, and extraordinarily lethal pathogens. The genetic tinkering which scientists have been doing in constructing hybrid models of DNA and the dangers inherent in the process have been of great concern to scientists themselves (4).

These and other developments may have caused much disenchantment in the young causing them to look to other fields and in some cases to revert to mystic, nonrational behavior. The uncertainty of the future, the perception of the triviality of the individual in the face of the cosmic forces unleashed, the perception that both gods and men have feet of clay have all helped to provide a fertile seed bed for the philosophical nihilism reflected in so much of the current social scene.

THE TEACHER AND THE SCHOOL

As schools have become more costly they have become increasingly under intense public scrutiny. And there has been increasing concern whether or not more costly education is necessarily any better education. A considerable amount of objective evidence does not suggest that it is. And although schools are frequently blamed for perceived failure to accomplish that which society expected it is doubtful whether the school should be asked to bear the blame fully or if indeed even a major portion of it. The authority of the schools and the teachers has been progressively eroded. A spate of court decisions has adversely influenced the schools ability to control and direct education and overly solicitous parents have intervened directly with the schools, with school board members, and in the courts to influence or change educational policies. So successful have been their efforts that schools have often failed to take actions which they knew to be proper and effective because they did not wish to face community harassment or the possible legal sanctions which a liberal judiciary was all too likely to impose. Judges have not been reluctant to assume the role of arbiters of educational policy although they would be the first to ruffle if educational leaders would have the temerity to suggest appropriate judicial policies for the legal profession. The result is that the schools are often essentially leaderless and they are prey to every passing nuance of pressure in the community.

230

The high cost of education has also caused governments at all levels to look for a more efficient educational system. The application of business and industrial methods to education seemed to many to be a logical direction to take. Thus a whole new set of procedures and terminology has developed in education accompanied by the usual acronymic array in all its glory, including PPBS (Planning, Programming and Budgeting System), CBTE (Competency Based Teacher Education), PBTE (Performance Based Teacher Education), PERT (Performance Evaluation Review Technique), WILKITS (Weber Individualized Learning Kits), and others. We have seen the rise of behavioral objectives which have probably done some good and have given better direction to teaching and had a wholesome influence on planning for, and evaluation of, instruction. On the other hand behavioral objectives are far from a universal panacea and J. Myron Atkins, Lee Cronbach, and others have ably identified their limitations. Many of these developments have tended to mechanize the process of education and the use of such terms as *input*, *output*, *feedback*, *product*, *recycle*, *system*, *contract*, and other terminology drawn from the business and industrial world are indicative of the trend. *Accountability* is one more shibboleth foisted off on the educational system and is another industrial procrustean bed more or less misapplied to a humanistic enterprise.

An examination of the research literature in science education reveals that whereas 35 years ago the concern was with science content, principles of science being a particularly big concern at that time along with concern for teaching methodology, a far higher proportion of the research can now be described as pupil oriented. This is but one more example of the anomalies we have in education where the educational process seems to be becoming increasingly mechanically and industrially oriented whereas research seems to be drifting more and more in the direction of focus on the student as person.

Much has also happened to teachers and their role. A quarter of a century and more ago professional associations really were professional associations. The name seems inappropriately applied to many organizations of teachers today. The organizations are now essentially welfare groups and the vocabulary of their meetings and committee work relates to professional negotiations, tenure, salary, working conditions, grievance procedures, arbitration, political platforms, and similar concerns. Teachers definitely have moved from professional orientation to a union orientation. This has tended to shift teacher focus from curriculum-teaching processes and students to legislation, committee work on welfare concerns, and union techniques in meeting problems. It has separated even further the administrative and teaching staff and further weakened the administrator's ability to lead. The rapid turnover in administrative personnel is a reflection of the difficulty and frustrations experienced by typical administrators.

In spite of all the alleged innovations in education and the immense amount of money spent on science teacher inservice education and mostly National Science Foundation (NSF) science curriculum projects, we seem to have a less efficient system of education and a poorer climate for student learning than we have had previously. The recent report by the Education Commission of the States (ECS) in their national assessment of educational progress program seems to provide at least some substantiation for this particular observation (14).

The shift in educational objectives of science instruction over the last 40 years is also instructive. In the thirties the Educational Policies Commission (EPC) and the Progressive Education Association (PEA) had major publications stressing the social objectives of science and problems of meeting the needs of adolescents (7, 11). Although later additions and refinements were made in treating science objectives the themes of social relevance and individual need tended to predominate until the onset of the NSF curriculum projects. At that time science educators lost their leadership roles and scientists preempted them. Only recently have science educators begun to reassume the leadership which they abrogated without a struggle. (The federal dollars have largely evaporated for large scale curriculum projects.) With the coming of the NSF curriculum projects there was a radical shift in the purpose of science teaching; it was to teach "real" science in depth. Scientists as a group had little faith in such pedagogical niceties as "objectives" and dismissed them as of low priority, of little consequence, and certainly not worthy of their serious consideration.

As a result, and hundreds of millions of dollars later, we find we bought a system which is no more effective than the one it supplanted and which has successfully alienated thousands of students from a study of science. Given the social context previously discussed it is possible that nothing could have been done to make any curriculum highly successful. But in a time when students were demanding "relevance" and a social awareness dimension in their education a curriculum emphasizing the quantitative, theoretical, and abstract aspects of science (or mathematics) was predictably not likely to be highly palatable educational fare.

Although objectives have recently enjoyed a resurgence and much attention is devoted to "behavioral objectives," criticism of this movement is common and, in the opinion of the writer, merited. Atkin's statement is a perceptive critique of the development (2). It is apparent that long-range and highly generalized goals and goals which are synthetic in the sense that they require the integration of content over time and perhaps from several fields are not well served by excessive preoccupation with behaviorally defined objectives. Some of these goals *should* involve the inculcation of values.

The ultra-liberals have objected to the notion that the inculcation of values should be included in the educational process. The schools have been chided for allegedly teaching middle-class values and have even accepted the criticism as valid. It is time to assert categorically that such middle-class values as honesty, individual responsibility, personal integrity, concern for others, and a belief in the work ethic had better be inculcated by the schools. To argue that many children do not have such values is to beg the question of the fundamental purpose of education. The function of education is to provide the essentials for successful individual and social life and values are a part of those essentials. Much of the social malaise of our time is tied directly to the lack of such values in a substantial part of our population. It is time to reexamine some of the broader social and individual objectives outlined by the EPC, PEA, and the Forty-Sixth Yearbook of the National Society for the Study of Education (NSSE) and perhaps mold and refine them in a format appropriate to today's needs (7, 8, 11).

TODAY'S STUDENT

One of the theses basic to this presentation has been that it is increasingly difficult to provide education for the young. Just as Bunyan depicts Christian's difficulties in his journey in *Pilgrim's Progress* the modern world has set out its own seductive enticements in a modern day "vanity fair." Neither adults nor children have been able to cope adequately with the opportunities for selfindulgence which the affluent society affords. A high proportion of children and youth are neglected to some degree. The prevalence of child abuse is well documented but the more diffuse general neglect of youth is far more common and an equally damaging state. Often in the midst of excessive materialistic trappings the child is deprived of what is needed most: parental love and attention, adult supervision, and genuine care and concern for the child as an individual. Instead, parents go merrily on their own existential way to jobs, golf, bridge, the bar, or other vanity enticements and the child is left alone for hours to lose himself in an endless series of television presentations or with other neglected children like himself to experiment with drugs, alcohol, sex, crime, or any combination thereof. The children in the grinding poverty of an inner city ghetto may often be no more neglected than their peers in suburbia.

For those who think the picture is overdrawn it might be instructive to look at the appalling statistics relating to teenage alcoholism, drug addiction, the epidemic spread of veneral disease, teenage crime and particularly crimes of violence, unwanted pregnancies, abortions and chronic promiscuity. The encroachment of television on family life and its stultifying effects on children have been examined by many thoughtful educators including Jerzy

Kosinski. Dorothy Cohen and Nancy Larrick (2, 5, 9). Some of the television viewing data cited indicate that when a child goes to kindergarten he is likely to have spent as much time viewing television as a college graduate has spent in college classes. Another statistic cited is that the average high school graduate will have spent 11,000 hours in school and 22,000 hours in front of a television set. A recent local study has indicated that 5th and 6th grade children were spending an average of 28 hours a week viewing television. The effect on the physical, social, and psychological development of the youn n onl be immense--and there are numerous indications that the eff is adverse.

In addition, the quality of television productions seems to become steadily more questionable. The r mantic scenes become continuously more explicit and the state of undress more complete. Alleged "comedy" hours become a series of thinly veiled double entendres about sex. The "police" shows capitalize on murder, rape, and other types of violence. It is a sorry show that doesn't have two or three corpses. Students would have to be slow learners indeed, if they did not gain a distorted notion of the world and gain a few pointers about how to commit a crime or practice seduction.

The plain truth is that the uality of life in a large number of homes is not very good. The family is often less a unit than a collection of individuals under a common roof. The causes are complex but existential doctrine, women's liberation, the pill, rapid transportation, the perceived need for two incomes, television, and the aftermath of a series of wars are all undoubtedly contributing factors. Whether we are set on an irreversible course is a large question. Some conditions seem unlikely to be changed. Yet, in some way, the direction must be changed. A continuation of the grim social trends identified above would raise the gravest questions of our ability to survive as a nation and as a society. It is well to remember that dictators have come to power when the state of social disintegration became intolerable.

What kind of attitudes, values, and motivations do children from such homes bring to school? Too often they are overstimulated and burned out, overindulged, underworked, and with abominable eating and sleeping habits. It is not difficult to see why efforts to interest students in the intricacies of cell structure or cell metabolism so often fall on sterile ground. In general the educational process in the classroom cannot compete with the pseudo glamor of the external world. Education is a time-oriented process and sound learning requires discipline and application over time--commodities not highly valued in current society. Students have had too much too soon and they have enjoyed the fruits of labor without the effort of labor There is a proverb that "a full lion does not hunt" and

234

an analogous one would be that "an indulged student is unlikely to labor mightily." In fact, the conditions so commonly prevailing seem ideally suited to the inculcation of a welfare mentality and to arrested development in a final state of chronic adolescence.

Having said all this, no intention is implied that the schools and teachers are or should be absolved of responsibility to do the best for youth that they can. It is only intended to indicate the immensity of the burden and the enormous difficulties involved. What can the schools and individual teachers do to counter the impact of a sick--some would say decadent--society? It is obvious that the answer has not been found and it may not even exist. But nevertheless new solutions must be sought.

SUMMARY

The tone of this presentation has been bleak and it was meant to be. Substantial changes need to be made to get all of education, including science education, back on a firmer foundation. Although many courses of action might be taken to improve the educational experiences of children, the following list of suggested problem areas is crucial and needs serious professional attention at once.

1. At the elementary and secondary school level, gear science education to serve the broader social and individual needs of general education and not be a training ground for miniature specialists.
2. Resist the erosion of standards. Education should be humane but holding to appropriate standards is not equivalent to inhumanity. As educators we have a responsibility to use all the resources available, including testing, guidance, and counseling to insure that children and youth are placed in educational contexts where they can succeed. They need their own ecological niche in the educational process. But this is not the same as lowering standards. The educational context should be suited to the talent, aptitude, and inclination of individual students. But when a student finds himself unsuited to a program, a new context is indicated rather than a lowering of standards. In brief, no one student is suited to all contexts but all should be suited to some context.
3. Reaffirm the need to stress values in education and resist the efforts of pseudo-liberals to deride "middle-class" values. These values have stood the test of time and are essential to civilized and humane social intercourse. Science is a good vehicle for conveying the values of honesty, integrity, and sound work and teachers need to accept such values as appropriate teaching objectives.

4. Seek a solution to the neglected child. If homes will no longer assume responsibility for the rearing of young then social alternatives must be evolved. Although the Chinese and Russian solutions to the problems of infants and youth may seem repugnant to us we may have no alternative to infant-care centers, child care centers, and youth work centers. The present conditions of social anarchy for youth cannot continue to prevail.
5. Reestablish by every conceivable means the autonomy of the local school board and the professional staff in the determination of educational policy and curriculum matters. Resist the encroachment of judicial, legislative, and bureaucratic agencies on the educational process. The stranglehold of categorical aid needs to be broken. Although science education has received enormous economic support it is doubtful that the benefits have been commensurate with the cost.
6. Whatever their concerns over the welfare aspects of being a teacher, teachers should not lose sight of the fact that they are professionals with professional obligations and responsibilities. The welfare of the child should not be subservient to the welfare of the teacher. The elected officers and boards of professional groups need to reaffirm their roles as policy and decision makers. More professionalism is needed.

REFERENCES

1. Atkin, J. Myron. "Behavioral Objectives in Curriculum Design: A Cautionary Note." *The Science Teacher* 35(May 1968):27-30.

2. Cohen, Dorothy H. "Is TV a Pied Piper?" *Young Children* 30(November 1974):4-14.

3. "Existentialism." *Encyclopaedia Brittanica, Macropaedia*, 1975, VII, 73.

4. "Genetics: Conference Gets Strict Controls to Replace Moratorium." *Science* 187(March 14, 1975):931-934.

5. Larrick, Nancy. "Children of Television." *Teacher* 93(September 1975):75-77.

6. Luce, Clare Booth. "The Significance of Squeaky Fromme." *The Wall Street Journal*, September 24, 1975, p. 24.

7. National Education Association. *The Purpose of Education in American Democracy*. Washington: NEA Educational Policies Commission, 1938.

8. National Society for the Study of Education. *Science Education in American Schools.* Forty-Sixth Yearbook, Part I. Nelson B. Henry, ed. Chicago: University of Chicago Press, 1947.

9. "A Nation of Videots: David John Interviews Jerzy Kosinski." *Media and Materials* 11(April 1975):24-26 ff.

10. "Objections to Astrology." *The Humanist* 35(September/October 1975):4-6.

11. Progressive Education Association. *Science in General Education.* New York: D. Appleton-Century Company, 1938.

12. *Rubā iyāt of Omar Khayyām.* Translated by Edward Fitzgerald, 1879.

13. Walsh, John. "Higher Education and Regulation: Counting the Costs of Compliance." *Science* 190(October 31, 1975):447.

14. "A Warning Signal? Science Knowledge Declines." *National Assessment of Educational Progress Newsletter* (March/April 1975):1, 3.

15. Wynne, John P. "Theory of Free Choice." *Philosophies of Education.* New York: Prentice-Hall, 1947, p. 175.

Edward Victor was born in 1914 in Massachusetts. He received his elementary and secondary education in Massachusetts schools. After completion of his secondary education Dr. Victor attended Harvard University from which he received his A.B. in 1935. He then attended Boston University and was awarded his A.M. in 1936 and his Ed.M. in 1941. He returned to Harvard University in 1955 and was awarded his Ed.D. in 1957.

Dr. Victor served as an instructor at New England College of Pharmacy from 1938 until 1941 and as an instructor at Boston University from 1941 until 1943. He was head of the Science Department at Westbrook Junior College in Portland, Maine, from 1944 until 1951, when he moved to Newport, Rhode Island, where he served as Science Supervisor until 1957. He has also taught in Puerto Rico. He served as a teaching fellow in education while pursuing his doctorate at Harvard University. After completion of his doctorate Dr. Victor was appointed Assistant Professor of Education at the University of Virginia where he remained for one year. In 1958 he joined the faculty of Northwestern University as a Professor of Science Education.

Dr. Victor has been active in numerous professional organizations, holding membership in AAAS, NSTA, NARST, AETA, CASMT, NEA, and the Illinois Academy of Science. He served as president of AETS during 1966-1967.

In addition to his responsibilities for science education at all levels at Northwestern University, Dr. Victor has been serving as a consultant to several publishing companies, educational film companies, and a science equipment company.

Dr. Victor has been an active author. He has authored or coauthored three books for use with prospective elementary teachers. His elementary science methods ~~book is widely used.~~ He has authored and edited a large number of science books for elementary schools and served as senior author for an elementary science text series. His articles have frequently been published in education and science education journals.

238

IN ELEMENTARY SCIENCE THE PENDULUM NEVER STOPS SWINGING

EDWARD VICTOR

Professor of Science Education
Northwestern University
Evanston, Illinois

From past history we have learned that when social and political upheavals take place the pendulum of change swings to the right or to the left. Sometimes the swing is a long one and other times the swing is short. Eventually the swing reaches its peak and then it inevitably begins its return toward the center. But some of the changes produced by the upheavals make a definite and permanent impact on our society.

The same effect holds true for changes in the teaching of elementary science. Some of the changes from new ideas and philosophies are incorporated to become an integral and permanent part of the teaching of elementary science.

Three comparatively recent changes in the teaching of elementary science immediately come to mind. Each change is worthy of discussion in quite some detail. In the first change, teaching the process skills of science, the pendulum has already swung to its peak and made its return toward the center. In the second change, teaching science by inquiry, the pendulum has just reached the peak of its swing and is now beginning its return. In the third change, teaching science by individualized instruction, the pendulum is only in the process of swinging upward and has not reached it's peak.

TEACHING THE PROCESS SKILLS OF SCIENCE

The National Society for the Study of Education (NSSE) has devoted three of its yearbooks to science education. These are the Thirty-First Yearbook, 1932 (3); the Forty-Sixth Yearbook, 1947 (2); and the Fifty-Ninth Yearbook, 1960 (1).

In the Thirty-First Yearbook the main thrust was to encourage teachers to avoid the teaching of facts and to concentrate on the teaching of concepts and conceptual schemes. In the Forty-Sixth Yearbook the emphasis shifted to include not only the teaching of

concepts and conceptual schemes--the content of science--but also the teaching of "functional" skills--the key operations, or process, of science.

Although elementary school teachers were now being urged to teach both the content and process of science, all too often the teachers still spent most of their time teaching concepts and conceptual schemes and paid little or no attention to teaching process skills. However, the pendulum of change had already begun to swing, slowly at first and then more quickly. Methods books, journals, and bulletins all began to stress the importance of teaching the process skills of science. The big push came with the Fifty-Ninth Yearbook which strongly recommended that science be taught as a process of inquiry involving the development of process skills.

Now the pendulum began to swing quickly. In the 1960s more than 10 elementary science curriculum projects were begun, all of them actively concerned with teaching the process skills. As materials were developed and disseminated by these elementary science projects the popularity of teaching the process skills grew. Now the swing of the pendulum reached its peak and, as is often the case when change takes place, there was a strong overreaction. For many, the teaching of process skills became all-important and the teaching of concepts and conceptual schemes was relegated to a secondary position. This overreaction even affected the use of other teaching techniques. Because elementary science had for too long been taught in a talk-talk-talk and read-read-read manner, these techniques became tabu. It is interesting to note that almost none of the new elementary science projects developed reading materials for the children. Also the project materials sharply restricted teachers from using teacher explanations or lectures.

Perhaps the reasoning behind these rather drastic measures seemed to be that since the teaching of process skills was now a main objective, only by eliminating reading and lecturing from the curricula of the new projects would this objective be attained. Many scientists and science educators, however, steadfastly maintained that the elimination of these teaching techniques, which are very effective when properly used, was just as unwise and impractical as the action of a parent who decides to chop off his child's left hand in order to make sure that the child will not become left-handed.

At the peak of the pendulum swing and its accompanying overreaction, the Science--A Process Approach program (SAPA) by the American Association for the Advancement of Science (AAAS) was perhaps the most well-known and widely used program. This program consists of a hierarchy of process skills to be learned but does

not include an equivalent structure of science content. Science concepts are introduced and taught only as they are needed to develop the appropriate process skills.

However, by the early 1970s the pendulum began to swing back toward the center again. The feeling steadily grew that process should not be the primary goal of elementary science and that content with a firm structure of concepts and conceptual schemes is an equally important goal. Eventually the consensus of opinion became that both goals are not mutually exclusive but instead are complimentary and mutually interdependent.

Of all the original elementary science curriculum projects only the following three have been commercially published and are in widespread use today:

1. Science--A Process Approach (SAPA).
2. Elementary Science Study (ESS).
3. Science Curriculum Improvement Study (SCIS).

The original popularity of SAPA definitely has been superseded by SCIS, whose program has combined a process approach with a structure of physical and biological science content. This is a concrete indication of the present trend to consider the goals of process and content to be equal in importance. The ESS program consists of a large number of individual units that use a process approach to teach concepts. Although the units do not make up a sequential science program, school systems are invited to develop their own science program by incorporating all or part of the ESS units into their program. A promising fourth project, Conceptually Oriented Program in Elementary Science (COPES), has developed a process-oriented program based on major conceptual schemes but to date has been unable to find a commercial publisher to publish the program.

So the pendulum has now returned towards the center, but not all the way. The pendulum swing served to bring sharply into focus the need for teaching process as well as content, a need which had existed for a long time. The new curriculum projects did much to ensure that the teaching of process skills received the emphasis it had so long deserved and enabled it to assume its rightful role in the elementary science program.

TEACHING SCIENCE BY INQUIRY

In the 1950s there arose a growing dissatisfaction among scientists and science educators with regard to the standard definition of *science* and its implications for the teaching of science in our schools. The standard definition was usually stated as "Science is a body of knowledge resulting from a process of inquiry." Both scientists and science educators felt that the definition should be stated instead as "Science is a process of inquiry resulting in a body of knowledge." As you can see, although the same words appear in both definitions the emphasis and thrust are different. In other words the feeling now was that science should be stressed and taught as a process of inquiry, not as a body of knowledge.

In 1960, when the Fifty-Ninth Yearbook of the NSSE strongly recommended that science be taught as a process of inquiry, the pendulum of change began to move. This movement was accelerated by the national science curriculum projects that were being developed, first for the high school, then for the junior high school, and finally for the elementary school. Because all these curriculum projects agreed with this philosophy that science should be taught as a process of inquiry, their programs became strongly committed to a teaching strategy that was highly activity-oriented.

A number of terms are being used to describe this activity-oriented teaching strategy. The three most common terms are learning by *inquiry*, learning by *discovery*, and learning by *investigation*. In the elementary school the lessons using activity-oriented teaching strategy are commonly called *discovery lessons*.

Discovery lessons follow a general pattern. First, a question or series of questions is raised. Through discussion a problem is identified, then the children--with the help of the teacher--propose ways of investigating the problem and gathering data Working either individually, in small groups, or as one large group, the children conduct investigations, gather data, and come to conclusions which they evaluate together. All this leads to new questions which identify new problems which require new investigations which produce new conclusions. In the process the children "discover" concepts and conceptual schemes.

The pendulum swing dealing with teaching by inquiry has already reached its peak. There are several distinct benefits to be derived from using this teaching strategy. First, the technique enables children to become participants, not spectators. This eliminates boredom, promotes both self-confidence and a feeling of accomplishment, encourages a greater reliance on the children's capabilities, and stimulates curiosity for further learning. Second, because this technique is highly activity-oriented it tends to develop the children's competency in the use of the process skills. Third, the inquiry procedures used in this technique are in complete agreement with the theories of psychologists like Jean Piaget and Jerome Bruner on how children develop intellectually and learn.

Now that the pendulum swing has reached its peak there are already signs that the pendulum will soon begin to move back toward the center. Like every teaching strategy, teaching by inquiry has its drawbacks as well as advantages. Educators and psychologists have discovered that learning by inquiry can be very difficult for slow learners because these children find it hard to persist in tasks that are not immediately fruitful. Some feel that a strong science background is a prerequisite for inquiry learning and, because elementary school children rarely have this background, inquiry learning will often falter and fail. Others contend that since there is a greater possiblity of failure with inquiry learning than with other strategies, this failure often tends to dampen many children's interest in learning further in science.

Finally, as it so often happens, many teachers who become highly enthusiastic about a new teaching technique again tend to overreact in the use of this technique and refrain from using other techniques that are also effective and even necessary. Everything in elementary science cannot be learned by inquiry only. It is difficult to have the children "discover" concepts and conceptual schemes in the areas of astronomy, geology, and physiology when there is so little opportunity to work with firsthand materials. Other techniques are necessary. In some cases a teacher explanation is essential. Sometimes reading, which is an integral part of the elementary school curriculum, is indispensable. Too often these two perfectly valid techniques have been misused when teachers made them their sole techniques for teaching science. However, eliminating these two techniques from elementary science in an effort to avoid their misuse is also wrong. Consequently those teachers who do not include other techniques when teaching by inquiry often run into difficulties that affect successful teaching and learning of science.

Furthermore a growing number of scientists and science educators have begun to object to the tendency of teachers to oversimplify the children's discovery of concepts and conceptual schemes. This is done by misleading the children about the actual time-consuming nature of inquiry and about the difficulties that scientists have encountered when using this process. As a result, teachers are leading children to "discover" in a few short days a concept or conceptual scheme that may have taken a scientist years and all kinds of difficulties to investigate and discover.

So the pendulum will soon begin to move back toward the center. Teaching science by inquiry has already made a tremendous impact upon elementary science. It will continue for a long time to be an outstanding, if not the leading, strategy for teaching elementary science. When used wisely with other effective teaching techniques it will help children successfully learn science both as a process of inquiry and as a structure of concepts and conceptual schemes.

TEACHING SCIENCE BY
INDIVIDUALIZED INSTRUCTION

All three yearbooks of NSSE have consistently urged that one of the key objectives of science teaching should be to help our children learn according to their individual abilities, needs, and interests. Until recently, however, the only provision made for individual differences in our science programs was the inclusion of additional learning activities for slow and fast learners. Although these activities were to be used as needed and whenever possible, too often the pressures of time and the inertia of teachers have restricted their use to a minimum.

Strangely enough, dissatisfaction with the new science curriculum projects has been instrumental in causing the pendulum of change to begin to swing towards the increased use of individualized instruction in the teaching of science. A prime factor is the inflexibility of the new programs which has caused concern to many teachers. They have felt constrained by the tight structure and rigid sequence of the learning activities which allow little freedom or provision for individual differences in teaching and learning. This concern has caused teachers to want to break away from the group instruction techniques implied by existing learning activities and to develop "individualized" activities of their own so that they could better tailor the rate, scope, and sequence of learning to the needs of their individual students.

At present there are three large-scale individualized science programs available:

1. The Individualized Science Instructional System (ISIS) project for the high school.
2. The Intermediate Science Curriculum Study (ISCS) project for the junior high or middle school.
3. The Individualized Science (IS) project for the elementary school.

All three projects are creating quite a stir in science education and the pendulum of change has begun to swing. Already there is a growing interest in teaching science by individualized instruction and it has become one of the hottest topics of discussion at local and national meetings.

How far the pendulum will swing before it reaches its peak is difficult to predict. Already teachers are encountering some difficulties with both large-scale and local individualized instruction programs. The biggest problem seems to lie not with the programs but with the children. Research has shown conclusively that fast learners do well with individualized instruction. But research

also shows that fast learners usually do well with any kind of instruction. However, slow and low-average learners usually do not do well at all with individualized instruction and the reason for this seems to be based upon personal characteristics. Recent research on the effectiveness of individualized science programs shows that slow and low-average learners usually do not like to work alone. They feel more secure when they work in large groups or as an entire class. Also they prefer to receive direction and instruction from the teacher during the learning activities instead of being forced to rely upon their own less-endowed creativity and ingenuity. Consequently it would appear that individualized instruction is not an effective teaching strategy for all children.

Despite these problems it is safe to predict that the current interest in individualized instruction will make an impact on elementary science. One result of this interest should be a greater effort to incorporate more and better individualized instruction into all science programs and this will help us come closer to achieving one of the major goals of elementary science.

IN CONCLUSION

And so it goes. As new ideas and teaching strategies emerge, the pendulum of change will swing. Then as the potentialities and limitations of each strategy are fully explored and realized the pendulum will swing back towards the center again. But the best of each idea and strategy will be incorporated into the teaching of elementary science, enriching all of elementary science in the process.

The request is constantly being made by teachers for guidelines as to which strategy is best to use when teaching science. In the light of all the changes that have taken place these past few years the answer should be obvious. No single strategy can be used to teach all aspects of elementary science. In every case select that strategy or combination of strategies that lends itself best to the effective learning of a particular process skill, concept, or conceptual scheme.

REFERENCES

1. National Society for the Study of Education. *Rethinking Science Education.* Fifty-Ninth Yearbook, Part I. Chicago: The University of Chicago Press, 1960.

2. National Society for the Study of Education. *Science Education in American Schools.* Forty-Sixth Yearbook, Part I. Chicago: The University of Chicago Press, 1947.

3. National Society for the Study of Education. *A Program for Teaching Science.* Thirty-First Yearbook, Part I. Chicago: The University of Chicago Press, 1932.

Fletcher G. Watson was born in 1912 in Maryland. He received his early education in Southern California. After graduation from high school he attended Pomona College (California) from which he received his A.B. degree in 1933. He went directly into graduate school in astronomy at Harvard University from which he was awarded both his M.A. in 1935 and his Ph.D. in 1938.

While pursuing his graduate studies (1933-1938) at Harvard University, Dr. Watson served as a graduate assistant and part-time instructor in astronomy. After completing his Ph.D. in 1938 he served as Executive Secretary and Research Associate at the Harvard University Observatory, a position he held until 1941 During 1941 he also served as an instructor of astronomy at Radcliffe College: During 1942-1943 he was a Technical Aide at the NDRC Radiation Laboratory at MIT. From 1943 until 1946 he served in the United States Navy. Dr. Watson was appointed Assistant Professor of Education at Harvard University in 1946. He was promoted to Associate Professor in 1949 and to Professor in 1957. In 1966 he was appointed Henry Lee Shattuck Professor of Education.

Dr. Watson has been active in science and science education organizations including NSTA, AAPT, NARST, AETS, AAAS, and American Academy of Arts and Sciences. He has assumed an active role on committees of these various professional associations.

In addition to his regular duties at Harvard University, he has been a consultant to NSF and assisted in a number of NSF institute and AYI programs. He has been a consultant to UNESCO in Paris, Latin America, and Thailand. Dr. Watson has been active in the curriculum development of the 1960's and 1970's.

He served on the steering committees of BSCS and of ESS and on the education advisory committee for NASA. Also, he was one of the co-directors of the Harvard Project Physics (now the Project Physics Course) curriculum development and previously worked with the Nigerian School Project.

Dr. Watson has been an active speaker, author, and researcher. His articles and presentations number over 100 and have appeared in recognized science and science education journals. He has authored an astronomy book and was coauthor of a popular science-methods book.

Dr. Watson's scholarship and service to science education have been recognized. He was graduated Magna Cum Laude in Astronomy and was elected to membership in Phi Beta Kappa and Sigma Xi. He was awarded a Ford Foundation Fellowship to study science education in Europe in 1964-1965. He was awarded a NSTA Citation of Distinguished Service in 1972 and was named Outstanding Science Educator of 1977 by the Massachusetts Association of Science Supervisors.

THIRTY YEARS IN SCIENCE EDUCATION AT HARVARD

FLETCHER G. WATSON

Harvard University
Cambridge, Massachusetts

On July 1, 1946, I became assistant professor of education at the Harvard Graduate School of Education (HGSE). Thus at the age of 34 I began my third career. I had just spent four and a half years in government service, one year at the Radiation Lab at MIT and three and a half years in the Navy responsible for computation of the tables and charts for the Loran system of long range navigation. Before that I had been at the Harvard Observatory for eight years, five as a graduate student and three as a junior staff member and researcher.

When I was interviewed for the position at HGSE the faculty asked me what I knew about "education." "Nothing" was my reply. The faculty said they knew that but wanted to hear what I would say. What was I doing as a proto-professor of education?

THE MAT PROGRAM

For reviving the Master of Arts in Teaching (MAT) program the faculty had decided to add instructors for various subjects who had some experience in the subject field. Their contention was that people who knew a subject could learn what was needed to know about education in contrast to the usual assumption that someone informed in education could effectively represent a field, in my case science. Three such appointments were made: in social studies, English, and science. However, the other two instructors left HGSE after three years to return to their academic specialty.

The Master of Arts in Teaching program had been introduced at Harvard in 1938 as an adaptation of the postgraduate diploma program in the United Kingdom. James B. Conant, president of the university, had attempted to revitalize the Graduate School of Education by establishing this program through which college graduates could become competent to teach their subject specialty in secondary schools. Initially the program had not gone well and it had been completely

disrupted by World War II. So in 1946 it was reorganized and new faculty were added. Gradually the program became known and students applied. The G.I. bill aided in financing some of the first students. My classes in the teaching of science were small, perhaps 10 students being the largest group.

Ignorant of educational theory, history, and practice, I had much to learn. Visits to nearby schools helped; at least I saw the mechanics of classroom operation. Talks with teachers added insight and talks with faculty colleagues, especially with William Burton also involved with the MAT program, added other points of view. Reading journals, *National Society for the Study of Education* (NSSE) yearbooks, and methods books helped some but these seemed shallow in terms of rationale. During the fall term course on methods of teaching science to students who had a wide range of scientific majors, I attempted to focus on lesson planning and tried to stress the general philosophical basis of science. Also I was concerned about the students having a knowledge of resources--journals, reference books, equipment suppliers, film sources, texts, and industrial free materials. Files of such materials were accumulated as references for planning and doing practice teaching. Happily, I soon met Paul Brandwein who gave similar instruction a Teachers College, Columbia. From him I took the idea of having students in training make card files of potentially useful resources, including price and complete reference, as well as their notes describing each entry.

With the help of colleagues I gradually developed contacts with science teachers who were considered outstanding and who were willing to take on practice teachers. I visited the practice teacher in school and assisted with the overall supervision. Probably this was a case of the "halt leading the blind" but with good humor the bright and committed students survived. Happily, satisfactory placements for them was no problem; many had several offers at outstanding school systems.

Major changes in the size and emphasis of the MAT program have occurred several times. The first came when the Ford Foundation made a large grant to HGSE to be expended over five years in support of teacher training programs. The "baby boom" was upon us and additional teachers for all levels were needed. Although a sizeable portion of the funds were used for scholarships and recruiting, additional faculty were added in several areas. An assistant professorship in science education was established and Abe Fischler from the Ossining Schools and Teachers College, Columbia University, was employed for three years beginning in 1959-1960. Dr. Fischler was primarily involved with an elementary school component of the MAT. Also, he worked closely with several of the doctorate candidates interested in elementary education and supervision. Maurice Belanger, one of our former students, took over for seven years and

in addition to being helpful with the doctorate students and those in masters programs did some significant research. After completing his degree, Douglas Roberts took over the MAT students for one year. Then Richard Weller carried that obligation for three years to 1971. By that time the elementary education program had withered away but other programs had evolved.

A DOCTORATE PROGRAM AND RESEARCH

A doctorate program and research were also among the activities expected of my position. Although the number of doctorate students in the entire school was small in 1946 I was encouraged by the admissions committee to take on some. For several of the initial admissions the program was a disaster. My criteria for admissions were vague as were the purposes of the students. Several withdrew from the school. Others hung on as part-timers for several years but then faded away. A few were so unsuccessful in their total program of study that their candidacy were terminated. The first success was George Davis who completed his thesis in 1950 on the possible uses by schools of town-owned lands in Massachusetts. George went to the University of Maine where with his ecological interests and good sense he developed a teacher program for developing science teachers, influenced statewide efforts, and established a doctorate program. He was followed by Francis McCarthy in 1951, Raoul Bowers in 1952, and then one or two per year until a bumper crop of six in 1961. By that time the "shop" was attracting numerous very able candidates.

Research is always of importance in a university but it takes time and money. To my pleasant surprise in the spring of 1955 Dean Keppel informed me that the Eugene P. Higgins Fund, in which the university shares, would provide several thousand dollars each year in support of research in science education. Approximately half of my salary for years was charged against the Higgins Fund while more recently, with a larger grant, all my salary and the operation of our "shop" has been supported from that fund. Initially the added funds were used mainly to employ psychological researchers to explore questions about the conceptual learning of science by young children. Susan Ervin, Janellen Huttenlocher, and Flores LeBeouf were the principal investigators. The results of their efforts were published mainly in *Child Development*.

In more recent years the funds were mainly used to support my students and their studies, especially for data-gathering and computer analyses. In addition, each year small funds were allocated to each doctoral student to assist him or her to attend at least one major professional meeting each year. Such contact is a component of professionalization. Also, being seen and sometimes

on the program for a presentation has aided students in obtaining subsequent employment. As many students have commented the availability of small amounts from the Higgins Fund has made a world of difference to them, their research, and their feelings of importance.

SCIENCE FAIRS

As a newcomer to science education I soon became aware of the routineness of much of the instruction offered in the schools. No significant opportunities existed for the potential scientific student to become actively involved in science projects and to obtain any recognition. Encouraged by Harlow Shapley, who was director of the Harvard Observatory, and by Watson Davis of Science Service (SS) (which Dr. Shapley had helped establish), I became an interested observer of the National Science Talent Search. Concurrently I recognized that the science fair program, sponsored by SS did offer just the sort of stimulation and recognition that I felt students should have. With Ralph Burhoe, then executive officer of the American Academy of Arts and Sciences whose central office is in Boston, we created the New England Science Fair. Because we wished to stimulate local fairs beyond the 12 being held in New England, we announced that entrants to the New England Fair had to be one of the top three winners in a local fair. Because the academy building did not have a large open hall, only 30 entrants could be accommodated. To lessen the tension on "winning" we created five "first" awards, 10 "second" awards, and all others received a "third" award. With a bit of publicity the number of local fairs rapidly mushroomed, doubling each year for a time.

We had, of course, involved a number of interested teachers on the steering committee. When the New England Fair was an established success the teachers committee took over the entire operation. With financial support from one of the local newspapers, each year they hold a large fair at the MIT cage with hundreds of exhibitors. In retrospect, it is pleasant to see that a small effort found a sensitive response from the teachers with the result that many students and teachers benefited from their involvement.

NATIONAL SCIENCE FOUNDATION

For two months early in 1953 I served as a temporary adviser to the newly created National Science Foundation (NSF) which was then beginning to explore possible programs and courses of action for precollege science courses and teachers. I had numerous interested discussions with Harry Kelly and Bowen Dees and others. At their request I submitted a series of memoranda outlining various possibilities; since these matched, at least in part, several actions

taken later by NSF I should note that my memoranda probably summarized points of view developed collectively with the NSF staff.

Subsequently I have served on various panels for NSF At no time did I wish to encourage an invitation to join the NSF staff. My responsibilities at Harvard have been sizable and increasing. Also rarely has there been a potential standin should I be away for a year or more. But perhaps most important has been my feeling since being in the Navy that I enjoyed being independent and personally responsible for my own actions. I am not a good "organizational man" and preferred not to seek an involvement within a bureaucracy.

ORGANIZATIONAL INVOLVEMENTS

As a member of numerous organizations in science and science education, I have served on a range of committees and attempted to be useful. When the Association for the Education of Teachers of Science (AETS) agreed to become a national organization and an affilitate of the National Science Teachers Association (NSTA), I was the first national president. Other than that I have not held nor sought elected office. Twice NSTA honored me by inquiring whether I would be a candidate for president. If one is a candidate there is always the chance that one might be elected to a position which involves a heavy investment of time for a three-year span. The first inquiry came as I was about to depart for England in 1964 and I declined because this was an inopportune time for me. The second inquiry came about 1967 when I was heavily involved with Harvard Project Physics (HPP) and again I decided not to be a candidate. In 1972 NSTA graciously presented me with a Citation for Distinguished Service to Science Education.

ACADEMIC YEAR INSTITUTES

NSF began funding Academic Year Institutes (AYI) in 1956 at three initial institutions. In 1957 Harvard was one of the institutions a[illegible]ed. Fifty experienced teachers of mathematics or science were recruited and enrolled. The director of AYI was initially Edwin Kemble of the Physics Department, a kindly and interested gentleman who had helped pioneer the General Education program at Harvard after World War II. For AYI, admissions and all administrative work was done by the School of Education. Charles Weller served as the first assistant director. Upon the retirement of Professor Kemble, Victor Guillemin became director for several years, and was followed by David Widder.

Although the prime purpose of AYI was to "upgrade" the academic backgrounds of the teachers through courses in arts and science and special courses for the group, I insisted that they were here at

government expense because they were teachers and would continue to be teachers. Therefore, some small portion of their time should be spent on aspects of teaching. I offered a half-course on the teaching of science and mathematics. In addition, AYIers were encouraged to take another half-course within education--psychology, test development, supervision, and so forth.

As policies changed in Washington, NSF opened more AYI programs to a maximum of around 40 per year and gradually reduced the enrollments in each program. Harvard's allotment went to 35 and then to about 20. Beginning in the mid-60s the shift for a few years was to support recent graduates like MATs entering teaching. Finally we enrolled only five experienced teachers as our last group in 1971-1972. Over the years Harvard enrolled more than 550 teachers in AYI. In addition to offering instruction, my role involved recruitment, selecting, program advising, and backup counseling. Despite the stress on these teachers--returning to the university after some years, being away from their friends and known environments, surviving on stipends less than their normal salaries--these were generally happy years. Many fine people were involved. Also, several made significant changes in their career lines and academic interests.

GENERAL EDUCATION

When James B. Conant published in 1947 *On Understanding Science* (3), later expanded as *Science and Common Sense* (4), it was an invitation to the Committee on General Education to request him to offer a course in that program. They asked. The course, identified as Natural Science 4, was first offered in 1947. To help put together a course of illuminating cases from the sciences, Conant asked a group of younger faculty to work with him during the several years he directed the course. Thomas Kuhn was from the areas of physics and the history of science, Leonard Nash was from chemistry, I was from astronomy and education. Duane Roller, Sr., from physics was with us for a year or two, as were several others.

This was an exciting involvement. We had no subject restrictions, only our knowledge of potential cases which would illustrate some significant aspects of scientific work and its influence on the general society. Conant, using some of the materials outlined in his book, developed a number of cases. Initially we used photocopies of the original papers and considerable ancillary reading, plus lectures, and laboratory-discussion sessions. Later many of the cases were edited into booklets. Kuhn treated the Copernican revolution, which became the basis for his first book *The Copernican Revolution* (6). I treated James Bradley's efforts to observe stellar parallax

which resulted in his discovery of the aberration of light, and later of the earth's nutation, as predicted by Sir Isaac Newton. Unwisely I did not publish the case.

SUMMER PROGRAM

These efforts modify college instruction in science led Conant to begin a series of brief summer meetings of interested college professors. The first such session in 1951 resulted in the book *Science in General Education* edited by I. Bernard Cohen and me (2). Another session was held in 1952 and one for 1953 was planned. But in January, 1953, Conant announced his retirement from Harvard. Announcements were out and we had to decide whether to cancel or proceed. With the help of Brandwein, who had been with us the previous summer, and Sydney Rosen we decided to proceed but to invite professors of science education and science supervisors from major cities to participate in a workshop on our collective problems. From this came the pamphlet *Critical Years Ahead in Science Education* (8).

Other special summer programs for science teachers were financed by grants from the DuPont Foundation and were held in 1954, 1955, and 1956 but ended when NSF Summer Institutes became available. Beginning in 1956 a special summer program on the biological uses of radioisotopes was held at the Harvard Medical School with sponsorship by the Atomic Energy Commission (AEC) and NSF, as well as Harvard University. For each of three years 20 carefully selected teachers were enrolled, were taught at the medical school for six weeks with lectures and laboratory work, and were loaned a sizable kit of detection equipment to take home. Since the intent of this rather expensive program was to have those enrolled serve as instructors to their colleagues at home--that is, to develop a chain-reaction--geographical location was important in the selection of participants. School superintendents had signed a statement in advance assuring that local efforts would be made to encourage the intended local implementation. To reveal what actually occurred, the grant from AEC-NSF allowed a follow-up reporter to visit each school district. Serving in this role were George LeSuer in 1956, Harold Miner in 1957, and George Weygand in 1958.

The results generally were very disappointing. Only in a few medium-sized cities such as Dayton, Ohio, were significant and successful efforts made to devise a local instructional program. In the large cities essentially nothing got organized. New York City, Philadelphia, Chicago, Los Angeles, New Orleans, St. Louis, Denver, Columbia, South Carolina, Washington, D.C. were unable or unwilling to use an expensively-trained teacher from their own staff to instruct others even when, in a few cases, we were able

to arrange local graduate credit for the instruction. This disappointing effort revealed to me the lethargy and cumbersomeness of administrative operations in large cities. Our attempts to create a chain reaction failed.

NEW CURRICULA

In 1956 when the PSSC group was organized at MIT I was invited to the first major discussion during December of that year. Since I was not acquainted with what was happening, I went only for the second day. Other science educators present included Morris Meister, Paul Brandwein, and Robert Carleton of NSTA, in addition to a number of nearby science teachers whom I knew. Inasmuch as the center of attention was on physics by physicists, and educators were frequently blamed for whatever seemed wrong, I saw no significant role for me, so I faded from sight and my absence seemed mutually acceptable.

About 1961, with Philip Johnson of Cornell and others, I attended an NSF conference to discuss possibilities of encouraging science curricular efforts for the elementary schools. Both Dr. Johnson and I had draft proposals in our pockets but we were soon told to sit on them as Educational Services Incorporated (ESI), the forerunner of the Educational Development Center (EDC), was already the chosen group. In the summers of 1962 and 1963 I was partially involved in ESS workshops. Also I was briefly on the ESS Steering Committee but as a real outsider and a professor of education I found that I was not sympathetic to the "messing around" approach then in vogue, so I withdrew when I went to England for the year 1964-1965.

During 1962-1963 I also served on the board of BSCS. By that time the designs of the several alternate BSCS courses were set and large scale trials were proceeding. As a member, with Paul Hurd, of the committee on teacher development we discovered that the congressional act specified the funds for precollegiate audiences. Since the teacher training would be done by college instructors we had no funds for operations. A pamphlet outlining possible ways to carry through teacher training was all we could create.

AAAS GUIDELINES

During these years AAAS was increasingly active in attempting to revise the guidelines on the training of science teachers. With numerous colleagues from science education, including Willard Jacobson, I attempted to make helpful suggestions. The effort lead by John Mayor of AAAS to cast the guidelines into behavioral competencies was an interesting exercise. However, because I was

painfully conscious of the degree to which any guidelines or state certification laws were continuously neglected by the schools, these efforts by AAAS seem interesting but unlikely to make any significant differences. This was when the wave of students following the "baby boom" of the late 40s and 50s was requiring even more teachers with the result that schools were hard-pressed to find even reasonably competent people as teachers. Despite the leadership of AAAS in attempting to improve the training of science teachers, I recall that my colleagues in the Association for the Education of Science Teachers (AETS) paid little or no attention to these restatements.

With David Newton in 1967-1968 we made the ROSES Study--Research on Science Education Survey. This was done at the request of AETS when no one else took the initiative or found the funds (the Higgins Fund covered much of the cost). From questionnaires and interviews with professors and students at many teacher training institutions we learned of the discrepancies between what seemed to be sensible programs of academi (scientific) training for future science teachers and what actually occurred. With a small grant from USOE we manufactured and circulated copies of the report to our colleagues but the silence was deafening. Possibly some programs were changed but we obtained no evidence of such action.

HARVARD PROJECT PHYSICS

ginning in 1962 Gerald Holton and James Rutherford, who had been a student with me and Holton, began a small-scale effort to rewrite Holton's college text *Introduction to Concepts and Theories In Physical Science* for potential use in secondary schools (5). A small grant from the Carnegie Foundation underwrote released time for Rutherford from his teaching in San Mateo and for materials for trials in two schools. Early in 1963 NSF held a meeting at which a recommendation was made to fund a second nationwide project in physics with rather different emphasis from that of PSSC in an effort to enroll more students in physics. With a new possibility opening, I joined with Holton and Rutherford to submit a proposal to both NSF and USOE. Early in 1964 this was approved and a contract was developed between Harvard University and the Office of Education with the understanding that NSF would, by interagency transfer, meet half the funding. On July 1, 1964, a small group of physicists, teachers, and secretarial staff met to begin the project later named Harvard Project Physics (HPP).

During the first summer we attempted to complete the rewriting of Holton's book to meet our obligations to the two trial schools. But very soon we realized that the rewritten text was too lengthy and that a new organization of ideas and "story line" was needed. During 1964-1965, while I was in England and on the continent on

sabbatical leave but with three trips back to Harvard, a new structure of six major units was developed and first-draft copy was roughed out. During the summer of 1965 we brought in 15 experienced teachers to become acquainted with the orientation of the course, review the draft text, and help develop appropriate laboratory activities.

Following trials of the 1964-1965 version and several two-day meetings with the trial teachers the entire course was rewritten for 1965-1966. From about 300 volunteers 35 additional trial teachers were chosen to be reasonably representative of all the schools nationwide in size and geography. Several well-known schools were excluded, e.g. Scarsdale and Grosse Point, for they seemed too atypical while Cedar Falls, Iowa, and Snowflake, Arizona were included. Lamentably we had few volunteers from the southern states but we included the one volunteer from Atlanta. These teachers met for eight weeks during 1966 at a summer institute at Pomona College for a thorough briefing with the materials.

Already some multimedia materials were being tried, especially some programmed instruction developed by Dan Smith and a special group. Film loops were being made by the National Film Board of Canada. Transparencies were being drafted. Articles for readers were being sought and trial readers were being produced for school testing. Unit tests were being developed and tried. Also, teacher resource books were being developed. By 1967-1968 we were, according to our contract, ready for a large-scale trial of the materials with a randomly chosen group of experimental and control teachers. The 36 experimental teachers in that group were briefed with the materials during 1967 at a summer institute at Wellesley College. The control teachers were brought in for a few days to inform them of their role in testing their students and to provide us with pertinent data about themselves.

By this time some 85 to 90 teachers were using the preliminary materials which were completely rewritten each year. Changes in concept sequence, time allocation, and emphasis were being made. New laboratory activities and equipment replaced those which proved either inadequate or faulty. The film loops were available for school trials as were the revised tests, readers, transparencies, programmed instruction, and teachers resource books. Also, the entire evaluation operation which had been tried with the 1966-1967 groups was ready to function.

The project was again funded for 1968-1969 and for a much lesser amount for 1969-1970 while the results were analyzed and the project closed down. Eventually, after negotiations, the expenditure of federal funds ceased on September 30, 1970.

By 1968 the three directors were actively seeking a publisher. Since the project had been developed under a public domain contract, anyone had the right to rewrite the materials for a commercial edition. As part of "anyone," the directors decided to engage in such a re-writing with the financial aid of a publisher. But which publisher? Separate and private discussions were held with about 21 publishers. Many offered to publish a text and student lab manual but no readers, programmed instruction, or other materials. Eventually two major publishers were willing to underwrite the entire diversity of materials and one was chosen. At his expense during 1969 and 1970 the entire set of course materials was revised for commercial publication for school use beginning in the fall of 1970.

Throughout these years the three directors/authors met officially at least once a week to decide on the wide range of questions needing attention. Rutherford was the fulltime executive officer who carried authority for all the operational activities. Holton and I continued as fulltime professors at the university meeting our classes, serving on committees, advising students, and so forth; no salary for our efforts was charged against the federal funds but rather these activities, in lieu of research, were part of the university and our personal contribution to the effort.

Commercial publication does not end involvement and concern but only changes the focus. The three authors continue to meet several times each year and are often in contact by telephone and mail. Since 1970 we have made the 1975 revision, produced an additional reader, edited and put through press three supplemental units, negotiated contracts for English language adaptations useful in Canada and in Australia as well as adaptations into Italian, Portuguese, Arabic, French, Japanese, and one into Spanish pending. Many visitors, including foreigners, come to talk about the orientations and materials of the course. There are, of course, numerous inquiries by mail and phone. I serve as the central clearinghouse for such inquiries and enjoy an interesting series of contacts.

PUBLICATIONS AND RESEARCH

As might be expected several of my publications have made use of my astronomical knowledge and interest in the history of science; Unit 2 of the HPP course materials is a major example. Teacher development, especially a concern for breadth of study in the sciences, has been discussed in numerous papers and chapters for anthologies. In retrospect it is apparent that most of these publications were intended to influence policy decisions and were not research in the empirical mode. However many of my research interests have been included in theses developed by students.

Books I have authored are *Between the Planets* (7) and coauthorship with Brandwein and Blackwood of *A Book of Methods for Teaching Science in the Secondary School* (1). A casebook on the evaluation of HPP written by Wayne Welch, Herbert Walberg, and myself was never accepted for publication (9). Publishers asserted that it was too narrow--only one example--which is just what we intended it to be. Perhaps it will be rewritten, for examples of large-scale evaluation and implementation efforts are scarce.

OVERSEAS INVOLVEMENTS

I have enjoyed various overseas activities beginning in 1958 as an Organization for Economic Co-operation and Development (OECD) observer at an international conference at Keele University, England, followed by participation in a similar session in Brussels in 1960. The most persistent and perhaps useful activities were around the prototype comprehensive secondary school created at Aiyetoro in Western Nigeria. In 1962 Harvard contracted with the Agency for International Development (AID) to provide partial staff and curricular advice in the development of a novel type of comprehensive school in recently independent Nigeria. With increasing industrialization desired by the Nigerians this school was to stress science and mathematics, even for the half of the students who would be enrolled only for two or three years rather than the five years to the O-level examinations. The U. S. science teachers, former Harvard University AYI students, along with other teachers of English, mathematics, and social studies, were induced to join the Nigerian staff to found and operate the school. Presumably they and their Nigerian counterparts were to develop curricula on the scene. As a result of one previous brief trip to Nigeria in 1961 I concluded that this would be almost impossible and that we should not send emissaries over there with empty hands.

During early 1962, with the help of Douglas Roberts, we outlined a possible program for the first two years of the school, Forms I and II. Plans for the three upper Forms III, IV, and V could wait until we had more experience. During August of 1962 the chosen teachers and several others worked in Cambridge to shape up possible material, to order appropriate laboratory equipment, and to modify the plans for the science building which was not yet completed. In 1963, after the school had opened, I attended a three-week conference in Ibadan where the American and Nigerian teachers plus several local advisers and representatives of the ministry of education met to make a first revision in the science courses. Subsequently I returned twice more in 1964 and 1967 to work on the curriculum to aid in training teachers from other interested schools throughout the country. Happily I have recently learned that the school, despite some modifications from the original plans, is a

successful and admired institution. The science program appears to be going well after further revisions and after the corps of American teachers had tapered off and then all had returned home.

Other international involvements have been with The International Union, Commission on Physics (IUCP) whose session in Eger, Hungary, I helped arrange in 1970. Through United Nations Educational, Scientific and Cultural Organization (UNESCO) I was involved in 1969 in an international conference on teaching science held at Reh voth, Israel. In 1971 six of us from the United States visited Japan, at their request, to describe HPP. Then in 1972-1973 I spent six weeks in Thailand as a constructive critic of the new physics course being developed under the auspices of UNESCO and the Thai government.

Interest in HPP also resulted in several trips to South America. In 1968 I was a member of a UNESCO Conference in Santiago, Chili, followed by a repeat performance in Cordoba, Argentina. In 1969 somewhat similar sessions were held in Sao Paulo, Brazil. Brief stops were also made in Venezuela.

MAT TERMINATION

By the end of the 1960s when federal support for scholarships in education and for curricular developments were drying up, the future emphases of HGSE received extensive discussion. The critical need for more teachers had ended and the MAT program seemed less necessary. Numerous students applied but placements were not so easily achieved. Further the dean continued to assert that the program was financially a drain although no specific budget figures were produced to counter those we made which showed that the school made a profit on the MAT program. Even I agreed that the MAT program for recent college graduates interested in teaching was not likely to yield major impacts on teaching and curricular uses in the schools. In the autumn of 1970 the dean appointed a number of committees to suggest alternatives. I headed a committee of which all the other members were on term appointments. To their chagrin they were put in the position of arguing for the continuation of their positions and employment. Ultimately we proposed a continuation of the subject area faculty with a shift toward enrolling experienced teachers who could modify school programs and the learning environments in schools. We lost. After many meetings and long discussions the faculty voted early in 1971 to terminate admissions to the MAT program and rejected the proposed shift to enrollment of experienced teachers. Thus by one decision the school ended its contacts with schools and schooling via teachers and curriculum development. Also it meant that the 16 term appointments would be ended. During the next year or two I helped my former

colleagues pack their books and carry them to waiting cars as they moved elsewhere. Other shifts in emphasis also occurred and three tenured professors resigned. I didn't.

Although I was heartsick from the decision and lack of like-minded colleagues, I chose not to resign. Retirement was only eight years ahead. A new dean was coming. Anyway I like the place and had no intention of moving or of appearing to have been forced out. Since I had not been working closely with the few MATs my instructional obligations changed little. However the subsequent demise of the AYI program removed the last of the experienced teachers who had been of such interest for many years. As a result of my previous involvement in a variety of curriculum development projects I began offering a general course on the "nuts and bolts" of curriculum development, ranging from ideas and people to publishers and implementation.

The doctorate program continued with some fine and exciting students. But we have gradually reduced the number admitted with the intent of having everyone degreed at the time of my retirement in June, 1978. Analysis with students of the four-year and then the seven-year longitudinal follow-ups on the students enrolled during 1967-1968 in the HPP trials, both experimental and control groups, is providing evidence about the developing career interests of this group of able young adults and their attitudes toward science and its involvement with social problems. Also, being chairman of the committee on degrees for three years has provided contact with many students throughout the school and allowed me to feel useful to the institution. Perhaps as a consolation prize the total financing of the "science ed. shop" was shifted from the dean's budget to an enlarged Higgins Fund grant administered by the president of the university.

When I initially made the shift from astronomy to education my previous mentor, Professor Bart Bok, said that I would lose my friends in science despite my continuing membership in Sigma Xi, AAAS, AAPT, and other groups. This was correct. Over the years I gradually chose not to attend the scientific colloquia held around the university on various esoteric subjects. I began to realize the social dimensions of educational efforts and the need for considering how the wide range of learners did learn what we presented. In a current report from the National Association for Research in Science Teaching (NASST) on potential research for submission to the National Institute of Education (NIE), I observed that "science education" was more appropriately seen as "education in science" and that of the two aspects "education" was primary. This appeared to disconcert some of my colleagues. Over the years I have moved somewhat from the reassuring identification of being a scientist, with all the ego-satisfaction it carries, to attempting to be a generalist concerned with children, learning, schools,

260

curriculum, teachers, instructional materials, finances, and the politics of implementation. Certainly a background of knowledge about the history and philosophy of science as well as assorted bits of very specific scientific information remains essential but to me the educational components have gradually taken precedence. The range of topics with which I should be competent is staggering; it ranges from sophisticated statistical procedures, through computer operations (which I never learned), the history and philosophy of science, the interaction of science in the social world (through both philosophy and technology), to learning theory, instructional procedures, school organization, and the development of insights by teachers. At best I have only a nodding acquaintance with many of these dimensions but a concern for them comprises the mix from which I attempt to guide students and make my own decisions.

The "science ed. shop" is known through the school as a happy place, perhaps a benevolent despotism. The continued opportunity to work with young, enthusiastic students spills over onto the faculty; we don't grow old. Central in the happy environment has been our devoted secretary and mother-surrogate, Sylvia Kovitz, who for 15 years has handled a multitude of responsibilities and personal problems with skill, sympathy, and discretion.

So there it is--the story of exciting involvements and inevitable disappointments with hints of my changes in perspective during 30 years. The inconsistencies of current curricula with the intensifying social needs for understanding what science is and is not and how results may be thoughtfully utilized by society cause me to be excited about the need for drastic curricular changes in substance and intent during the years just ahead. Science education continues to be an exciting, dynamic study having increasing social importance.

REFERENCES

1. Brandwein, Paul F.; Blackwood, Paul E.; and Watson, Fletcher G. *A Book of Methods for Teaching Science in the Secondary School.* New York: Harcourt, Brace and Company, 1958.

2. Cohen, I. Bernard, and Watson, Fletcher G. (eds.). *Science in General Education.* Cambridge: Harvard University Press, 1952.

3. Conant, James B. *On Understanding Science.* New Haven: Yale University Press, 1947.

4. Conant, James B. *Science and Common Sense.* New Haven: Yale University Press, 1951.

261

5. Holton, Gerald. *Introduction to Concepts and Theories in Physical Science.* Cambridge: Addison-Wesley, 1973.

6. Kuhn, Thomas S. *The Copernican Revolution.* Cambridge: Harvard University Press, 1957.

7. Watson, Fletcher G. *Between the Planets.* Rev. ed. Cambridge: Harvard University Press, 1956.

8. Watson, Fletcher G.; Brandwein, F.; and Rosen, Sydney (eds.). *Critical Years Ahead in Science Teaching.* Cambridge: Harvard University Press, 1953.

9. Welch, Wayne; Walberg, Herbert; and Watson, Fletcher. "A Case Study in Curriculum Evaluation: Harvard Project Physics." Mimeographed. Minneapolis: University of Minnesota, 1971.

Stanley E. Williamson was born in Nebraska in 1910. His early education was obtained in Kansas and Nebraska schools, but his higher education degrees geographically cover the United States. He was awarded his B.A. from Nebraska Wesleyan University in 1931, his M.A. from Teachers College, Columbia University in 1936, and his Ed.D. from the University of Oregon in 1955.

After graduation from Nebraska Wesleyan University Dr. Williamson served five years as a secondary biology teacher and as chairman of the science department in a Nebraska high school. From 1936 until 1943 he served as science supervisor and chairman of the science department of the University High School, University of Oregon. He served as principal of the University High School from 1943 until 1946, when he moved to Oregon State University as Professor of Science Education and Chairman of the Department of Science Education. Dr. Williamson served as chairman until 1972 when he was appointed Dean of the College of Education at Oregon State University, a position he held until his retirement in 1975. He was awarded the rank of Emeritus Dean of the College of Education and Professor of Science Education in 1975.

Dr. Williamson has been active in numerous professional organizations including NSTA, NARST, AETS, NSSA, NABT, AAAS, and The Oregon Science Teachers Association. He was elected a fellow of AAAS. He held offices in NABT including Vice-President in 1968. He served as Western Vice-President of NSTA from 1953 until 1955. and was national president in 1963. He also served two terms on the NSTA Board of Directors and was awarded the Robert H. Carleton Award in 1973.

In addition to his regular duties as Professor of Science Education and Department Chairman, Dr. Williamson directed numerous NSF institute programs between 1957 and 1975. He served on the BSCS Committee in Teacher Preparation and on the Steering Committee from 1964 until 1970. He taught in India as part of a U.S. AID program in 1966 and directed institutes in Hawaii during the summers of 1967, 1969, and 1970. He has served as a consultant in Australia and was a member of the Oregon State Standards and Practices Committee of the State Board of Education for six years serving one year as Vice-Chairman.

Dr. Williamson has published in education and science education journals. He coauthored a chapter in the 59th NSSE Yearbook and books on science supervision and science teacher education. He has contributed chapters to several curriculum and science education publications.

SCIENCE EDUCATION IN THE TWENTIETH CENTURY

STANLEY E. WILLIAMSON

Professor Emeritus
Dean of School of Education and
Professor of Science Education
Oregon State University
Corvallis, Oregon

During the past 75 years there have been numerous changes in education, and more specifically in science education, than in any period in American history--changes in basic educational philosophy, learning psychology, curriculum, and methods of teaching. From the beginning, schools in America were established with the belief that a democratic form of government depends, for its values and effectiveness, upon citizens educated to understand and direct intelligently their lives and the affairs of the nation. To achieve this goal the basic principles of American education focused on such terms as: *free and universal, publicly supported and controlled, nonsectarian and compulsory,* and *with equal opportunity for all.*

Such a system of public education must through necessity closely identify with the society which nurtures and supports it; in turn this system of public education invariably is influenced by social conditions prevalent in that society. At any given time in history crises in society directly or indirectly effect school organization, financial support, programs, and teaching emphasis. Reviewing the problems and issues in science education during this century is a review of American history--the crises and the periods of great growth and progress. Programs in science education have adjusted to changes in society by frequent modification of philosophy, objectives, curriculum, and teaching strategies. Science program changes have not always been the result of careful and deliberate planning on the part of science educators for periods of social crises demand immediate action in the solution of social, political, or economic problems. As a result leaders in science education have been forced many times to play a "catch-up" role rather than a "leadership role" in the research and development of the kinds of programs most appropriate for a specific time and place in history.

Education, especially science education, has been periodically severely criticized throughout this century by professional groups, the news media, scientists, and the lay public. Critical questions have been raised regarding the general relevance of science programs,

quality of the curriculum, teaching procedures, and teacher effectiveness. While critical of science and science teaching, most acknowledge the fact that science and technology have played an extremely important role in the evolutionary development western culture. The problems that emerged from applying scientific advancement and technological developments were complex and difficult to solve for they permeated every segment of society. Man has found it more and more difficult to come to terms with nature, to live with it, to understand it. and to control it. Scientists and technologists have created a new kind of world and have had, and will continue to have, great influence on the social, political, and economic segments of our culture.

While science and technology have made many contributions to society they have at the same time created problems, many of which should be concern to science educators. In 1964 Polykarp Kusch stated:

> Science has all but banished the need for superstition and the blind acceptance of dogma; it has taught man that the Universe is ordered and has revealed the elements of that order. It has, with technology, shown man how to improve his physical conditions of life, and has greatly enlarged the dimensions of man's world through travel and communication.

He further reminds us

> ... that though sci ce has removed the need for superstition and the life of extreme hardships, both superstition and hardship persist in the lives of a large percentage of the inhabitants of this earth. For others, science has in their minds and emotions become the object of the same mystical reverence that the priesthood of an earlier era enjoyed--it is believed to be the source of all wisdom and truth to which access is so difficult, the rights of initiation to the cult so arduous that access must be denied except for a few of the elect (8).

The explosion of scientific knowledge during this century has resulted in a certain mysticism about science, a belief on the part of some in the magic of science which often leads to mistrust. Everett Mendelsoln alluded to this in suggesting that

1. The arrogance of contemporary science must be replaced with modesty.
2. Accessibility is a must for science--allow people in, demystify the knowledge, using language understood by the general public.

3. Science must be reconstructed to be nonviolent, noncoercive, and nonmanipulative.
4. Science must be in harmony with nature (9:7-8).

One may question the effect science teaching has had during this century in producing significant changes in the public's view of science.

The task of the science educator in preparing youth for decision making in a complex technological world becomes more difficult with each passing year. Not only must students understand structure, processes, and conceptual schemes of science but limitations of science as well. As one reflects on the changes in science education during this century several key questions come to mind: What progress has been made in the basic philosophy of science education, curriculum, and teaching strategies? What conditions in society have influenced these changes? What has been the role and responsibility of science educators in initiating change? How successful are current science programs in meeting the needs of youth preparing to live in the twenty-first century? Regardless of the many efforts made to improve science education during the past 75 years we enter the last quarter of this century with many unanswered questions, unsolved problems, and unresolved issues.

SOCIAL CRISES INFLUENCING SCIENCE EDUCATION

In a democracy, schools are inevitably influenced by the wishes and demands of the society which gives them support. While they are but one agency among many responsible for transmitting culture, schools appear to be the only agency which society, broadly conceived, directly controls economically and politically. As a result society expects the schools to meet its needs in good times and in periods of crises. A review of the history of American education during the twentieth century reveals that it is the periods of crises that have had the greatest impact on society and in turn the schools. To really understand the development in science education during the past 75 years it is essential that one study the major social crises to discover their impact on public education and the attempts made by science educators and others to assist society in seeking solutions to its problems.

The Enrollment Crisis at the Turn of the Twentieth Century

With the dawning of the twentieth century came ever increasing numbers of youth seeking real or imagined benefits from education. Increased enrollment (500 percent between 1890 and 1915) brought a radical change in the concept of American education, both elementary and secondary. There was a move from the European pattern of

education for a select few to schools responsible for educating all the youth of America. There was widespread dissatisfaction in society with the static organization and offerings of schools and dissatisfaction with the schools' inability to meet the interests, needs, and abilities of a more heterogeneous enrollment. The junior high school evolved as an important part of the reorganization movement and was designed to provide

1. Greater opportunity for teachers to experiment with curriculum materials, thereby adopting content and methodology to the needs of students.
2. Programs that would enable some students to terminate their educational program in the ninth year.
3. Exploratory courses that prepared other students for further study in high school and college.

With the junior high school came significant changes in the science program. Attempts were made to design new courses (fused or integrated) in biology, general science, and practical courses in the physical sciences. General science, in particular, became popular and provided opportunities for curriculum innovations, experimentation, and research. Several factors contributed to the rapid acceptance of general science and other science courses offered at this level, namely:

1. Students leaving school after the 9th grade, frequently as high as 40 percent.
2. Need for knowledge of the physical sciences in studying the biological sciences.
3. Need for an introduction to each of the sequence of high school science courses.
4. Decline in enrollment in secondary school science courses.

This marked the first real effort on the part of science teachers to break from tradition by actually preparing and experimenting with course materials that adapted content to the pupils' immediate environment using large unit areas such as atmosphere, earth, life, and energy or through attempts at integration. The new programs were most successful. Enrollment in science increased and the program received general acceptance by the Central Association in 1913, by the Committee on Reorganization of Science in 1920, and by the Committee on Teaching Science in 1932. While much effort was given to the junior high school science curriculum during the first quarter of this century, it reached a plateau and remained relatively static for the next 50 years. Content has vacillated from science topics, to broad environmental problems, back to content again depending upon periodic conditions and the needs of society. Although experimentation continues in curriculum design and development at this level, there is little evidence that science programs for junior high school students

today are any better. Neither have current curriculum materials solved the problems identified by science educators at the turn of the century. The question remains: What knowledge is of most worth--for youth at this age level, living at this time in history, in this social setting, and beset with problems of this ever-changing technological world?

The junior high school science program was quite well-conceived with adequate objectives, content, and teaching method but the implementation of the program was severely handicapped by inadequate provision for the preparation of general science teachers. Few colleges of education had programs for the special preparation of teachers working at this level in terms of philosophy, psychology, curriculum design, and methodology. Prospective science teachers were generally given extensive preparation in one or more of the basic sciences and thus failed to see the importance of integrated courses designed to meet the interests, needs, and abilities of a heterogeneous group of students. Thus far science educators have failed, for the most part, to resolve this problem through modern teacher education programs.

Effect of World War I and II on Science Education

Before the public schools made satisfactory adjustments in facilities, curricula and teaching practices to meet the enrollment crisis, World War I became a reality. Wars in the twentieth century were global in nature using many of the world's resources, both human and physical, thereby disrupting the normal lives of people of all ages. Such a crisis situation placed special pressures on the schools to provide trained personnel in the basic sciences, health sciences, and for young men mentally and physically prepared for service in a war-torn world. Society demanded immediate program revisions to offset such apparent inadequacies.

Change was slow and difficult and 23 years later with the beginning of World War II many of the same problems still existed. Now the crisis in society was even greater than before, resulting in many crash curriculum changes in science, health, physical education, the languages, and in the social sciences. Science educators responded by making major adjustments in course offerings and in developing numerous specialized courses such as preflight aeronautics, fundamentals of radio and/or electricity, and other courses directly related to the war effort. Crash science programs, usually lacking in thoughtful planning and development and designed to solve special programs, are usually of short duration; this was especially true of science courses designed during this period for 10 years after World War II. Most specialized courses were dropped from the science program as tensions in society eased.

World War II was a war of technology. Society had accepted that technology with its requisite demands was a basis for survival in a peacetime world. During the war years the value of the science instruction as revealed by science courses was seriously questioned. The emphasis on consumer and general education in the depression years was in conflict with the needs of a technologically-oriented society and career needs in highly specialized fields. Whether science should be functional in meeting the needs of young people or should be taught with emphasis on the scientific enterprise and the preparation of scientists and engineers was the subject of numerous debates. The reports of special committees and/or commissions--such as the National Committee on Science Teaching in 1942 (4), the Educational Policies Commission (EPC) in 1944 (6), the Harvard Report: *General Education in a Free Society* in 1950 (14), Science and Public Policy--President's Scientific Research Board (13), and the National Society for the Study of Education's (NSSE) Forty-Sixth Yearbook *Science Education in American Schools* in 1947 (11)--recognized the importance of science K-12 in maintaining a democratic society and recommended that science programs be designed to provide scientific literacy for all and individuals who are prepared to assume active roles in a scientific and technological society.

Because of the immediate needs of the war years improved teaching procedures and curriculum reform never fully materialized. The lack of a viable learning theory and a shortage of qualified teachers and school facilities and equipment made curriculum innovation and research all but impossible. However, society became fully aware of the importance of science in preparing literate citizens and in solving the problems and issues of the day.

The Depression Years

For the first 30 years of this century education had the support and confidence of the American people. With the beginning of the Great Depression in 1929 this attitude changed. The schools and other social institutions were severely criticized as being aimless and ineffective, lacking in leadership and programs appropriate for the times. Educational budgets were slashed for the first time in American history. The number of students per class increased, the school year was shortened, annual salary increments for teachers denied, and building programs curtailed or eliminated. Teachers and administrators felt punished by society because educational theories were being challenged at a time when demands on schools were increasing due to the depression. Special criticisms were made of elementary and secondary schools for low standards of discipline, quality of the curriculum, and inadequate preparation of teachers.

Professional educators rebuked the teachers for their self-satisfaction and inertia, charged the schools with responsibility for the spread of crime, political corruption, and increasing divorce rates. Some critics believed that from 30 to 50 percent of the subject matter content of the curriculum could be deleted without loss to students or society. Even the press contributed to the frustration of administrators and teachers through its criticisms--never had so much been written about the schools.

As in previous social, political, or economic crises situations school personnel reacted to the criticisms by rethinking educational philosophy, learning psychology, curriculum materials, and teaching methods. Curriculum committees, national organizations and associations, and commissions made significant reports based on the ever-increasing importance of science and technology and the personal, social, and economic welfare of individual students. Many were critical of science courses based on the memorization and recitation of unrelated facts and encouraged the development of courses that emphasized change in attitudes, development of problem solving abilities (thinking), and the intelligent self-direction of students.

Two publications appearing during the depression period--the NSSE Thirty-First Yearbook, *A Program for Teaching Science* in 1932 (10), and the *Progressive Education Association Science in General Education* in 1938 (1)--greatly influenced science education during this period and for years to come. To many science educators they stand as milestones in the history of science education. The committee preparing the NSSE Yearbook considered every major problem in science education:

1. Development of a theory of science education.
2. Aims and objectives.
3. Selection of course content.
4. Organization of content (units).
5. Suggested teaching and laboratory procedures.
6. Evaluation.
7. The sequence of courses.

In the final analysis this yearbook made three major contributions--all of which were new concepts to the field--to science teaching:

1. It supported a K-12 science program.
2. It organized course content around the major principles and generalizations of science.
3. It emphasized the importance of teaching procedures.

Science in General Education was a report of the committee on the function of science in general education of the Commission on Secondary School Curriculum established by the Progressive Education

Association (PEA) in 1938. This publication reported on:

1. A basic point of view on the purpose of general education in a democracy and the function of science teaching in relation to it.
2. Analysis of the role of science teaching in providing experiences in personal living, in immediate personal-social relationships, in social-civic relationships, and in economic relationships.
3. Understanding the student as a unique personality and evaluating his progress toward an ever-increasing personal adequacy and social effectiveness.
4. Suggestions on how to meet student needs, how to understand the student, how to reorganize courses, and how to build resource units.

A chapter on "Teaching Science in Ways to Encourage Reflective Thinking" is a highlight of the book and served as a model for future curriculum design and development.

Both publications were to have a profound influence on science education for years to come and for the first time in this century efforts were made to develop a theory of science education based on viable learning theory and tailored to meet the needs and interests of students rather than adult needs as conceived by previous teachers or curriculum makers. Greater provision was made in curriculum planning for student initiative and participation. Subject-matter lines became less important and content was organized around broad topics, problems, and projects that were closely related life activities of youth. Some efforts were made toward developing integrated courses, particularly in the earth and physical sciences.

Progressive education rose to prominence during the depression years. In fact it served to meet the social needs in a period of crisis and began as a part of a humanitarian effort to apply the promise of the American dream--an effort to improve the lives of all American youth. Lawrence Cremin defines progressivism in education as meaning:

1. Broadening the program and function of the school to include direct concern for health, vocation, and the quality of family and community life.
2. Applying in the classroom the pedagogical principles derived from new scientific research in psychology and the social sciences.
3. Tailoring instruction more and more to the different kinds and classes of children who are being brought within the purview of the school.

4. The radical faith that culture could be democratized without being vulgarized; the faith that everyone could share not only in the benefits of the new sciences but in the pursuit of the arts as well! (3:viii-ix)

Progressivism in the thirties was essentially a worldwide response to industrialism. Its failure, if one insists that it failed, was due to the efforts of critics to express disapproval of the present in favor of the past. The concept of progressivism was challenged because of an erroneous and superficial understanding of its philosophy and procedures on the part of those attempting to implement it into a program of action. This was not only true in general education but in science education as well. However, the results of well-designed research programs show that progressive education properly applied did prepare students who were not inferior in basic fundamental education as some predicted and did reveal superior growth in self-reliance, initiative, creative abilities, and self-expression. It became apparent during the depression that schools were only one means of transmitting culture among many other agencies; each social organization had its own curriculum whether it be the family, the church, the employer, or any other group and each teaches just as deliberately and systematically as the schools. Progressivists advocated that it was the responsibility of the school to work co-operatively with each group for effective and complete learning.

Programs in science education during the depression years were modified quite drastically in an effort to meet the identified needs of students. Changes were made in basic philosophy with major emphasis on reflective thinking, personal health, personal-social relationships, social-civic relationships, and economic relationships; in content selection and organization (broad units); in teaching strategies, student activities, and in evaluating student progress. Efforts were made by some science educators to correlate science with other subject areas (English and/or social science), to integrate the basic science areas into one general course (physical science, consumer science) and to make all science courses more practical for students. As a result school districts, curriculum consultants, and teachers spent much time and effort in designing and writing new courses of study in science and in developing many new courses of programs without the benefit of funding outside the local school district.

It is interesting to speculate on "what might have been" had the educational and learning theories of the thirties not been interrupted by another major social crisis--World War II. There are definite continuities and similarities between attempts for educational reform today and the progressive education movement of the thirties. Social conditions in a highly affluent society have problems similar to those in a deeply depressed society--the need

to understand the world we live in, to develop a workable value system, to acquire the skills necessary in decision making, and to learn to control individual and group behavior in a responsible way. These are of utmost importance in a technological society.

Today's science educators may find much food for thought in a careful study of science education during the depression years and the contributions made by the progressive education movement. The work of John Dewey, William H. Kilpatrick, Joseph Justman, George S. Counts and the numerous reports of EPC and many other individuals and/or groups may be most helpful in analyzing societal problems and in determining the role of science education in planning for the future. If nothing more, such a careful study may in part remove the necessity of rediscovering the wheel every 20 years or so.

Science Education in the Space Age--Crisis in the Classroom

Following World War II local, state, and national groups began studying the changes and/or improvements needed in elementary and secondary school science teaching. Industry designed, developed, and distributed many new science teaching materials and in some instances provided funds to support science teachers attending special summer institutes for curriculum study and revision. With the launching of the first Russian satellite in 1957 the federal government, through the National Science Foundation (NSF), provided funds to support the development of new curriculum materials and to retrain science teachers. This interest in science education was in fact due to the explosion of scientific knowledge, the influence of World War II on the growth of science and technology, and the need for scientists and engineers.

For the second time within a period of two decades the schools were severely criticized by segments of society who were protesting the inadequacies and inequities of science programs and courses. The problem was further complicated by the fact that the critics were polarized with some believing in strict regimentation and highly structured, theoretical science courses and others advocating a more flexible, practical approach in an effort to meet the needs of youth. Because of the immediate needs of society for scientists and engineers the former group was more persuasive in receiving grants for curriculum design and development.

The literature on science education during the late fifties and sixties was abundant and controversial. The National Science Teachers Association (NSTA) position paper on curriculum development in science argued for three aspects of the scientific enterprise to be included in the science curriculum:

1. Descriptive science or natural history as a basis for scientific inquiry.
2. Science proper, for its intellectual challenge.
3. Technology for its practical application (5).

The association through its conference of scientists in November of 1963 attempted to develop a "theory of science education" by Paul DeHart Hurd in its publication *Theory Into Action* and to identify the conceptual schemes and major items in the process of science (7:5-15). Many other individuals, groups, or associations joined in the debate. Two publications appeared during this period which had some impact on educational procedures--A. S. Neill's *Summerhill* in 1960 (12) and Charles Silberman's *Crisis in the Classroom* in 1970 (15). Both authors argued that the crisis in the schools was little more than a reflection of the crises in American society and their suggested recommendations for improvement were similar to those suggested by the progressive education programs 30 years before.

In the final analysis the pressures of a technological society and its need for scientists and engineers prevailed with the development of curriculum materials that were rigorous, theoretical, and of high quality. In a 15-year span millions of dollars were spent on designing science courses K-12, on classrooms and equipment, on teaching aids, and on teacher preparation. Interest was generated in science teaching and the needs of science teachers and the lay public became aware of the importance of science in solving mans' social, political, and economic problems. As good as the newly designed curriculum materials appeared to be, certain weaknesses became apparent--they were not based on a common theory of science education in the overall education program, on common objectives, or on a general notion as to just what contribution science education should make to the individual and to society. Lacking this sense of direction, groups preparing curriculum materials appeared to go their separate ways having in common severe criticism of existing science courses and the general notion that whatever was produced in the way of curriculum innovation and revision "if it was good for science, it was good science." This is not to imply that the efforts of curriculum makers during the sixties were wasted time and effort--not true. For the most part these curriculum makers were interested and dedicated individuals and for some it was a great personal and professional sacrifice to work at an activity for which they lacked preparation in philosophy, psychology, and in some instances professional education. They were successful in producing greater numbers of scientists and engineers to help society through the crisis of the space age. However, as in the past, curriculum materials conceived in a period of crisis are subject to question and since they are revolutionary rather than evolutionary they tend to lack the flexibility needed in a rapidly changing society.

It must be said, in all honesty, that many of the new courses never had the chance for success they rightly deserved. Professional educators, scientists, and politicians could not have predicted the social changes in America and in the world that occurred during the mid-sixties and early seventies. The war in Vietnam, space exploration, national and international political scandals, the energy crisis, population control, and the over-production of specialized personnel together produced a new crisis situation in society. It was a period of questioning the programs of science education in the schools, the goals of society and social unrest particularly among the young, and a search for relevance. Again science programs were challenged as to their effectiveness in preparing young people with the kind of tools needed in decision making and in solving a multitude of social, political, economic, and environmental problems. Again society called for an evaluation of its schools, demanding an educational program designed to meet change and the preparation of youth capable of influencing the direction of change so that further crises might be avoided. It appears, on analysis, that past science programs have been too self-contained, lacking in their effort to relate to the total environment, other institutions, or agencies of learning. To be most effective, science programs should be developed that interrelate with other areas of the curriculum, with the environment, and with all aspects of society. This may be one way that members of society may solve and/or resolve crisis situations and it may be the only way crises can be avoided.

IN CONCLUSION

For three-quarters of a century science education has been in a state of crisis and confusion in terms of a viable theory, content selection and organization, teaching methodology, and evaluation. Through the years many changes in individual science courses and in program design have been attempted but always in an effort to adjust to an existing crisis in society and infrequently revealing the thoughtful, evolutionary development--so desperately needed--based on research, preparation, and experimentation. With a new social crisis occurring every 10 to 15 years and with the accelerated developments in science and technology it was all but impossible for curriculum makers to adjust courses and programs to rapidly changing needs of society. Unfortunately science educators did not assume, or were denied for one reason or another, an active leadership role in the orderly preparation of science programs needed to prepare scientifically literate citizens who are capable of living in, and adjusting to, a world of change.

There are many lessons to be learned from the efforts made, and experiences gained, in science education over the past 75 years. The frequent efforts to rethink the science curriculum has not at

this point in time provided a viable theory of science education--one designed to meet the challenge of change in a modern technological world with its many problems and provide the intellectual tools necessary for life in the twenty-first century. We enter the last quarter of this century searching for science curriculum materials that have survival value, that prepare young people to understand change, and that accept some responsibility in directing change.

The acquisition of propositional knowledge, scientific skills, and the understanding of biological and physical phenomena in science teaching is not enough. Of equal importance, and possibly for life in the next century of even greater importance, are habits of reflective thinking, attitudes and interests that enable one to live in, and adjust to, changing cultural conditions. EPC provided a sense of direction in this area in its publication *Education and the Spirit of Science* in 1966 by identifying seven values which underline science and should be required in the education of youth. They are:

> (1) Longing to know and to understand, (2) Questioning of all things, (3) Search for Data and their meaning, (4) Demand for verification, (5) Respect for logic, (6) Consideration of premises, and (7) Consideration of consequences (5).

To teach for these values would require considerable modification of existing theories of science education, content selection and organization, and teaching procedures. It would demand that science education, scientists, psychologists, social scientists and philosophers work together over an extended period of time in planning further evolutionary developments in science education. Curriculum design and development cannot be entrusted to a select few representing subject areas or special groups but must include the input from many segments of society and draw from other institutions involved in the educative process.

One can be sure that periodic crises in society, both nationally and internationally, will continue in the future. It therefore seems imperative that we not only plan for crisis situations but that serious study and consideration be made of the conditions and events influencing science education in the past. To prepare for changes in society is no easy task for [illegible] do not know with any degree of certainty what discoveries in scien[illegible]r developments in technology may have impact on society and i[illegible]urn on the schools. A clue to what is needed may be found in George S. Counts' *Education and American Civilization* when he writes:

There is no quick and easy way to a great education. There is no simple device or formula for the achievement of this goal. Such an education cannot be derived from a study of the process itself, nor can it be found in the interests of children, or in any number of "great books." It can come only from a bold and creative confronting of nature, the values, the conditions, and the potentialities of civilization. An education can rise no higher than the conception of the civilization that perceives it, gives it substance, and determines its purpose and direction (2).

And so it is with science education for an adequate program cannot come from the study of science and the processes of science alone, or from the immediate interests of young people, or from the immediate needs of society, or from elaborate theories of education Rather an adequate program in science education must come from the study of, and reflection on, the knowledge and aspirations of the society which supports the scientific endeavors and gives it purpose and direction.

It is time for a critical evaluation of what we have done, what progress has been made, and where do we go from here. What is needed is not another curriculum writing project, at least not until there has been sufficient time and effort spent in researching our successes and our failures the needs of society, and what is really needed from science education to cope with the problems of tomorrow. The past 75 years have been exciting in science education; the challenge of tomorrow make the years ahead appear even more so.

REFERENCES

1. Alberty, H. B. (chairman). *Science in General Education.* Report of the Committee on the Function of Science in General Education. Commission on Secondary Curriculum, Progressive Education Association. New York: D. Appleton-Century, 1938.

2. Counts, George S. *Education and American Civilization.* New York: Bureau of Publications, Teachers College, Columbia University, 1952.

3. Cremin, Lawrence. *The Transformation of the School: Progressivism in American Education 1876-1957.* New York: Alfred A. Knopf, 1961, pp. viii-ix.

4. Croxton, W. C. (chairman). *Redirecting Science Teaching in the Light of Personal-Social Needs.* National Committee on Science Teaching, American Council of Science Teachers. Washington: National Education Association, 1942.

5. Educational Policies Commission. *Education and the Spirit of Science*. Washington: National Education Association, 1966.

6. Educational Policies Commission. *Education for All American Youth*. Washington: National Education Association and American Association of School Administrators, 1944.

7. Hurd, Paul DeHart. "Toward a Theory of Science Education Consistent with Modern Science." *Theory Into Action*. Washington: National Science Teachers Association, 1964.

8. Kusch, Polykarp. "The Values and Limitations of Science in a Modern World." *New Knowledge: Its Impact on Higher Education*, ed. H. C. Taxon. Corvallis, Oregon: Oregon State University Press, 1964.

9. Mendelson, Everett. "Values and Science: A Critical Reassessment." *The Science Teacher* 43(January 1976):20-23.

10. National Society for the Study of Education. *A Program for Teaching Science*. Thirty-First Yearbook, Part I. Chicago: University of Chicago Press, 1932.

11. National Society for the Study of Education. *Science Education in American Schools*. Forty-Sixth Yearbook, Part I. Chicago: University of Chicago Press, 1947.

12. Neill, A. S. *Summerhill*. New York: Hart Publishing Company, 1960.

13. Steelman, John R., Chairman. *Science and Public Policy*. 5 volumes. Washington, DC: U.S. Government Printing Office, 1947.

Volume	I	A Program for the Nation	August 27, 1947, p. 73
Volume	II	The Federal Research Program	September 27, 1947, p. 318
Volume	III	Administration for Research	October 4, 1947, p. 324
Volume	IV	Manpower for Research	October 11, 1947, p. 166
Volume	V	The Nation's Medical Research	October 18, 1947, p. 118

14. Report of the Harvard Committee. *General Education in a Free Society*. Cambridge: Harvard University Press, 1950.

15. Silberman, Charles. *Crisis in the Classroom*. New York: Random House, 1970.